Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

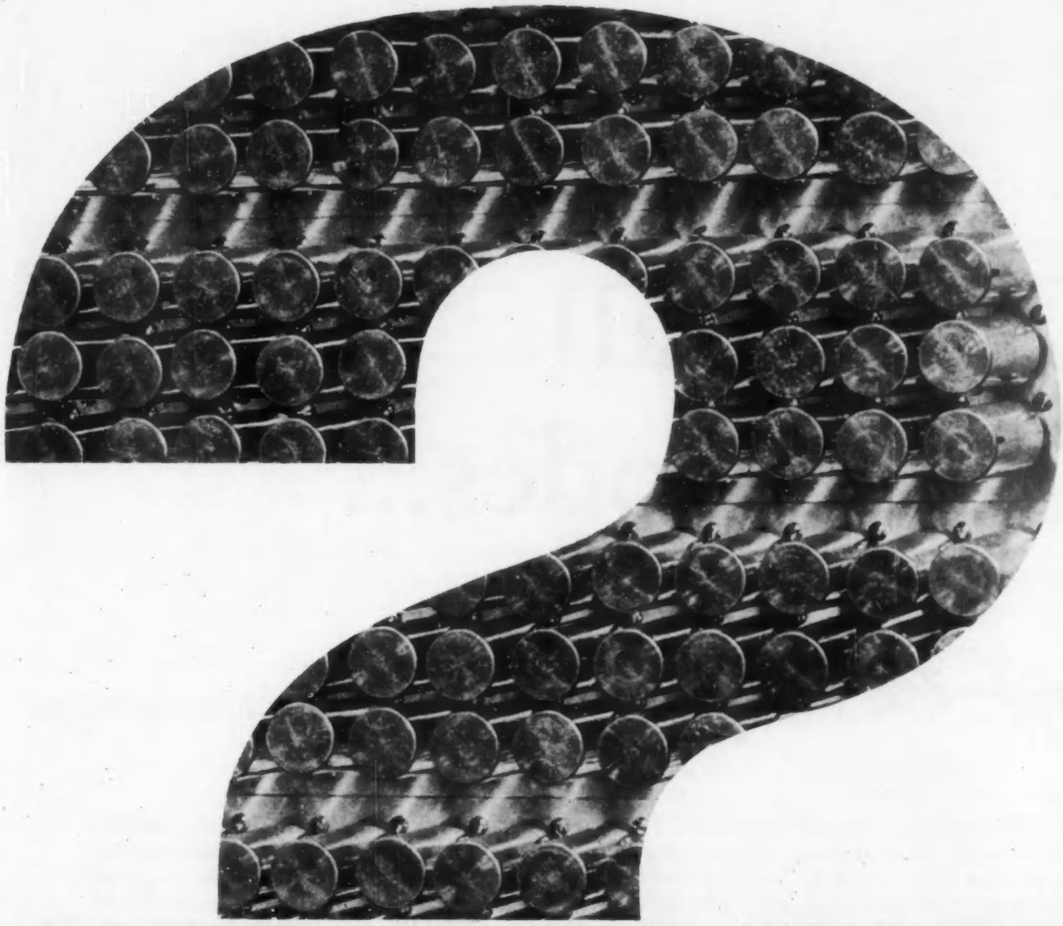
A McGraw-Hill Publication

75 Cents

DECEMBER 1961

- √ **Feedrate Override Limits Tool Stress**
- √ **Servoed Antenna Tracks Radio Pill**
- √ **Positive Metering for Small Flows**

Ideas at Work



HOW RELIABLE ARE DIGITAL CIRCUIT MODULES

IF YOU KNOW THE ANSWER, CAN YOU PROVE IT? ■ Calculations can be misleading ■ Ballyhoo proves nothing ■ Opinions can be biased. ■ We didn't have an answer, so we took 1,000 of our T-101B Flip-Flop circuit modules – $34,000 worth – from stock and plugged them into a system. Since that time, these units have been operating 24 hours a day at maximum frequency and under heaviest specified load . . . Now we're waiting for a failure. ■ At 1,000,000 hours of operating (1,000 units x 1,000 hours) there were: ■ No infant failures ■ No random failures ■ No wear-out failures ■ Just no failures of any kind. The test is still running. Watch for our next ad. Maybe by then we will have a failure to report. Our Applications Engineering staff stands ready to serve you in implementing your digital systems block diagram. Write, wire, or phone today for further information on any of our families of digital circuit modules or on this life test.

ENGINEERED ELECTRONICS Company

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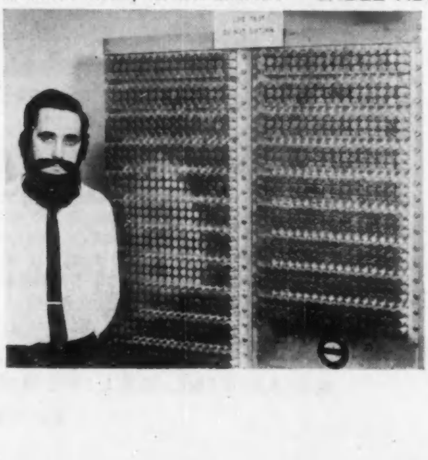
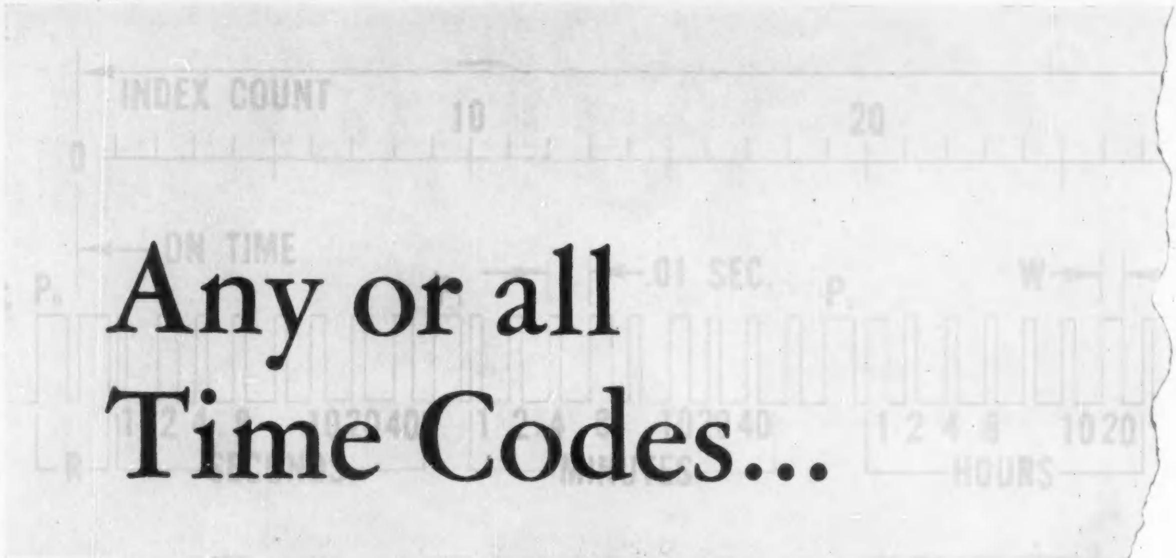




Any or all Time Codes...

off-the-shelf from **ASTRODATA**

ASTRODATA can give you, in *one standard* instrument at *standard* instrument prices, any presently used time code format or up to 8 codes simultaneously. You can choose from more than 30 standard options, all immediately available off-the-shelf. Only Astrodata can honestly make this offer.

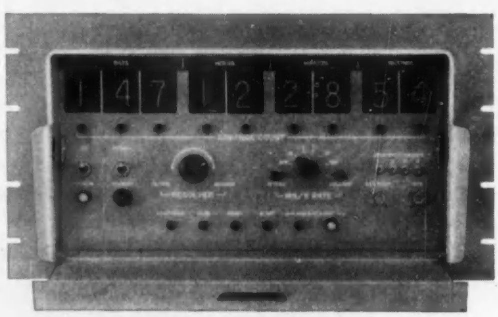
Astrodata's complete line of solid state time code equipment is built to MIL requirements around modular plug-in circuit cards. Right now cards are on the shelf for all time code formats in use today, including IRIG Members A, B, C, and D; NASA 36-, 28- and 20-bit; Atlantic and Pacific Missile Ranges, Eglin, White Sands, etc.

Using these standard modules, and combinations thereof, Astrodata supplies "custom" generators/translators in the shortest possible time and for the lowest possible price. No costly engineering design is involved.

Astrodata's approach also avoids early obsolescense. The user can add and subtract modules with ease; instead of a complete new generator or translator, he orders new cards as he would spare parts. As new code formats are developed, Astrodata develops new plug-ins at once.

We invite you to investigate, and will be happy to supply names of customers in your area.

Example of Astrodata Time Code Equipment



SERIES 6190 TIME CODE GENERATOR

Available for generating all time code formats; stability, 1 part in 10^8 per day with internal frequency standard, also precise synchronization to external frequency standards; multiple, simultaneous serial time code outputs; 8 simultaneous pulse rate outputs, (1 mc per second to 1 per minute); 3 optional interchangeable plug-in power supplies (60 cps, 400 cps, 28 v/dc); completely transistorized.

Free TIME CODE FORMATS

New brochure includes all commonly-used time code formats compiled for easy reference, and details on Astrodata equipment. For your copy, write to Astrodata, Inc., 240 E. Palais Road, Anaheim, California, Phone PR 2-1000 or TWX AH 5327.

ASTRODATA INC. *Successors to Epsco-West*

ANAHEIM, CALIFORNIA

Control ENGINEERING

DECEMBER 1961

VOL. 8 NO. 12

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

Continued on next page ▶

IDEAS AT WORK

WHAT'S NEW IN THE CONTROL FIELD

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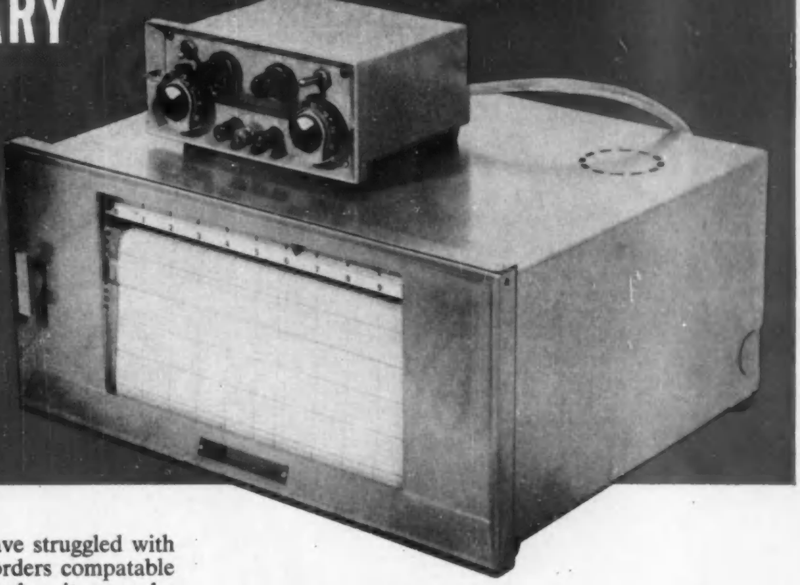
REVOLUTIONARY NEW CONCEPT IN RECORDING!



For years instrument users have struggled with making their potentiometer recorders compatable with changing input needs. Today it may be necessary to measure temperature, tomorrow pressure. In order to be prepared to meet these changing demands it has been necessary to stock a number of recorders, or spend hours in modifying existing input circuits.

This costly and outmoded instrumentation is no longer necessary! Westronics, Inc. now brings to the industry a totally new *UNIVERSAL RECORDER* featuring panel or table mounted *EXTERNAL PLUG-IN* input modules. Each has in itself a maximum of versatility.

The Standard Universal Recorder is completely self contained: Ready for millivolt or thermocouple recording (changeable by means of *INTERNAL PLUG-IN RANGE CARDS).*

By simply connecting one of the *EXTERNAL INPUT MODULES* to an existing receptacle on the rear of the instrument, its uses are extended to: *ADJUSTABLE SPAN AND ZERO, RESISTANCE BULB CALIBRATION, STRAIN GAGE MEASUREMENT,* and *MANY OTHER USEFUL FUNCTIONS!*

MODERN DESIGN

Everything about the new Westronics Universal Recorder is modern. Nothing old fashioned about this one! Note these features:

- COMPACT DESIGN (Only 8⅝" high)
- ZENER DIODE STANDARDIZATION
- PULL OUT CHASSIS
- PLUG-IN AMPLIFIERS
- BALL POINT PENS (That Really Work!)
- QUICK CHANGE CHART SPEED SELECTOR (No gears to change)

QUALITY

The new Westronics Universal Recorder features a servo system that uses ball bearings throughout. The pen carriage utilizes ball bearing motion on a precision ground track. No troublesome sheet metal parts sliding on rods on this one. Smooth ball bearing floating action is what makes dependable Ball Point inking practical.

VERSATILITY

The new Westronics Universal Recorder is second to none in versatility. Available in 5" and 11" strip chart sizes, single pen, 2 pen and multipoints.

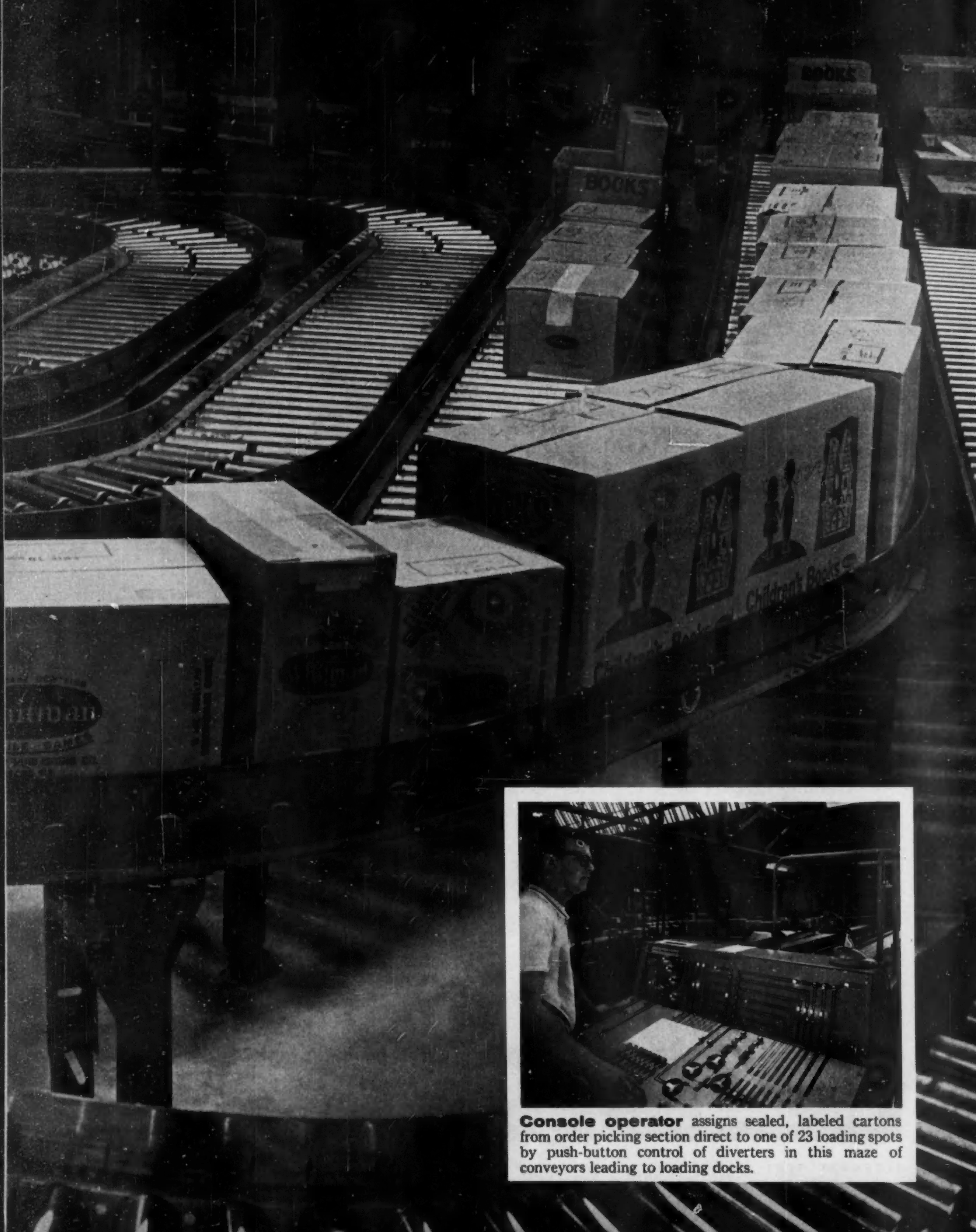
ALL THESE FEATURES AND A COMPETITIVE PRICE TOO!

CALL ON ONE OF WESTRONICS 23 SALES-SERVICE REPRESENTATIVES TO HELP YOU SPECIFY A WESTRONICS UNIVERSAL RECORDER TODAY.

westronics, inc.

TWX FT 8248 U • 3605 McCART STREET • FORT WORTH, TEXAS

WHAT'S NEW IN CONTROL FOR AUTOMATED CONVEYOR SYSTEMS?



Console operator assigns sealed, labeled cartons from order picking section direct to one of 23 loading spots by push-button control of diverters in this maze of conveyors leading to loading docks.

SHOPTALK

Computer Equipment Comparison Series . . .

When the Computer Equipment Comparison Series was being considered for publication in this magazine, we had not the slightest doubt as to the present and future value of each article as it appeared. Since the publication of the initial article in October, its reputation as a valuable reference has been well established. (This issue carries Part 3, page 105). On completion, the series will constitute a comprehensive collation of features and characteristics of digital computer systems published in compact form for easy reference. From past experience, we are certain that reprints will be in great demand.

. . . Reprints by subscription

Rather than wait for completion of the series—perhaps a matter of two years—to issue a package reprint of all articles, we have decided to offer article reprints of the entire series on a subscription basis.

Here's how the reprint subscription service for the computer equipment comparison series will work: On receipt of an order (see page 174), we will send the subscriber a gold-embosed, three-ring, Lexide binder complete with reprints of all articles in the series published to date. Shortly after succeeding articles appear in CONTROL ENGINEERING, they will be reprinted and mailed automatically to subscribers.

For quality, permanency and usefulness, the articles will be reprinted on one side only of individual, prepunched, 70-pound coated sheets, ready for insertion into the binder. Since so much of the material in these articles is in tabular form, foldout sheets will be used as needed to assure that all large tables are horizontal for easy reading and data comparison.

You get the over-all series by completing one order blank. We keep our handling and billing costs down to provide you with a sturdy binder, all reprints and periodically updated contents page for only $10 if you send check, money order, on your company purchase order with the order coupon, or $12 if you ask to be billed later. (Prices are for U.S. and Canada; overseas, $16 paid with order. Quantity prices will be provided on request.)

Control Engineering Annual Index

At the back of this issue is the index covering the material published in CONTROL ENGINEERING in 1961. It has been organized on a key-word basis to aid you in locating information on major subjects, and by article author. A quick estimate shows the index covers about 800 pages of editorial material published this year.

WIRE AND CABLE ROUND TABLE

CONTROL ENGINEERS:

Save 20-35% installation space with Du Pont plastics

You have asked...

Q: What is the straight story on the flammability of polyethylene?

A: Polyethylene is rated as a "slow-burning" material, like rubber and many other materials. Its performance in flame tests depends on the construction. For instance, #6 AWG copper line wire with 2/64" of ALATHON 5, BK22 polyethylene resin passes the horizontal flame test. If you need a truly "self-extinguishing" insulation which will pass the U/L vertical flame test, use Du Pont RULAN flame-retardant plastic (based on polyethylene).

Q: What is the best nylon and best polyethylene for outdoor service? How long will they last?

A: The best outdoor nylon is ZYTEL 37X nylon resin. It contains well-dispersed carbon black, and a good heat stabilizer. We do not know yet what its outdoor life will be, but it has stood up over 17,000 hours in the Weather-O-Meter (unfiltered arc) without failure.

ALATHON 1000 BK-30 is Du Pont's best polyethylene resin for outdoor service. It should be good for well over 20 years (possibly over 40).

Q: I have had trouble with thermoplastic jackets splitting and jamming conduits during pulling. Do you know a good lubricant?

A: Maybe you're using the wrong thermoplastic. We are having great success with jackets of ZYTEL 37X. This product is extremely hard and slick, exceptionally tough, easy to pull. 37X looks good for direct burial cable, too, where you have especially tough plowing conditions.

Du Pont does not manufacture wire and cable, but supplies thermoplastic resins for insulation and jacketing.

Extensive research has shown that the properties of ALATHON polyethylene resins permit a thinner primary insulation with equal or better dielectric performance than other compounds. Result: smaller over-all cable diameter and smaller conduits are practical. Depending on the number and size of conductors, savings of 20% to 35% in thickness over the older constructions are thus possible.

For extreme cases, where the possibility of fire precludes the use of polyethylene, Du Pont recommends the use of RULAN, a flame-retardant plastic, in the same thickness as ALATHON. For secondary insulation, a thin skin of ZYTEL nylon resin imparts exceptional abrasion resistance and higher operating temperature limit. Where mechanical abuse or chemical attack pose a problem, an armor of ZYTEL gives maximum protection.

A typical control cable design that takes advantage of the superior properties of Du Pont plastics is shown at right. For complete information on the use of ALATHON, RULAN and ZYTEL for improving signal and control cable design, send for your copy of Polychemicals Department Booklet WC-3 "Signal and Control Cable Design." Write: Du Pont Company, Rm. CE-12, Polychemicals Dept., Wilmington 98, Delaware. *In Canada:* Du Pont of Canada Limited, P.O. Box 660, Montreal, Quebec.

POLYCHEMICALS DEPARTMENT

DU PONT

Better Things for Better Living . . . *through Chemistry*

ALATHON® POLYETHYLENE RESINS | **RULAN®** FLAME-RETARDANT PLASTICS | **ZYTEL®** NYLON RESINS

FEEDBACK

Accord on editorial

To the Editor—

The editorial in your August issue is a pertinent and timely message. If your plea to electronic control systems purchasers to put a realistic price tag on potential problems is heeded it will certainly result in more intelligent initial purchases and fewer long-term disappointments.

Day after day customers purchase complex electronic control systems on price. Penetrating engineering evaluations of various equipments are becoming increasingly rare, despite their increasing importance. Frequently the reason for this is the user's inability to accurately evaluate complex electronic control systems, particularly when bids have been received from as many as a dozen suppliers. However, without such an evaluation, users cannot anticipate the differences between equipments with respect to:

1) Probable differences in performance.
2) Ease of operating the equipment properly.
3) Costs of operating the equipment.
4) Ease of training maintenance people.
5) Probability of frequent failures.
6) Potential electronic problems, such as pickup, "noise", etc.

We would like to echo your view that the purchaser visit users of similar equipment and see whether they are satisfied and what their performance and maintenance experience has been. We would only suggest that the prospective purchaser evaluate the equipment and its performance himself, based on his own standards. This should protect him, at least in part, from the tendency of users to justify their purchase by painting a rosy picture of the performance of the equipment they may be stuck with.

G. D. Fowle, Jr., Head
Systems Section
Market Development Div.
Leeds & Northrup Co.

Teaches Languages Too

To the Editor—

I enjoyed the interesting article on page 26 of your October '61 issue dealing with programmed learning materials. However, there was one error in a reference to our client, Encyclopaedia Brittanica Films, Inc.

The list of courses stated that EBF has no programmed courses in languages. Actually, the company is currently marketing programmed courses in Introductory Spanish, Spanish A, German A, and French Phonetics.

Raymond J. Blair
Anna M. Rosenberg Associates

A Question of Sensitivity

To the Editor—

I was very interested in the article "Hall Effect Transducers", September '61 issue, p. 138. One of my areas of interest with Helipot is a new group of Hall effect voltage generators.

The rapid progress in the development of Hall generators is indicated by our Model 80B. This generator is a vacuum deposited film of indium antimonide. The very thin film which we use can have an input impedance ranging from 100 to 800 ohms. Using special techniques we can go even higher. We can produce any desired input impedance within this range. Normal production tolerance is plus or minus 25 percent. The output impedance holds pretty closely to one-half the input impedance. These high impedances greatly ease the problem of matching the transducer to other electronic equipment.

While the high impedance and thin film do not allow the Model 80B to put out the 3.5 volts mentioned in the article, we do have a significant advantage in sensitivity over any other Hall generator known to me. Mr. Wood's article did not mention sensitivity but, for transducer application or signal generation, this is perhaps the single most important parameter of a Hall generator. The Model 80B has a minimum sensitivity of 2 volts per ampere-kilogauss. By special selection we can achieve as high as 6 volts per ampere-kilogauss. This sensitivity approximates a full order of magnitude over that of other Hall generators.

George R. Keller
Manager, Special Products
Helipot Div.,
Beckman Instruments, Inc.

The high output Hall probe referred to in the article is the Siemens SV-130A distributed in the U.S.A. by Instrument Systems Corp. Like the Beckman 80B, the SV-130A is a deposited film device made of indium antimonide. It has a sensitivity of 10 volts per ampere-kilogauss, input im-

FEEDBACK

pedance of 200 ohms, and output impedance of 140 ohms. Ed.

Missed Computer Standards

To the Editor—

The article in your October '61 issue by Dr. H. L. Mason "Control Terminology—A Report on U.S. Standards Activity", p. 67, is a very worthwhile step in the direction of informing your readers of standardization activities in the automatic control and computer fields. However, the article did not give complete coverage to IRE activities in the area of computer standards. In addition to the Proposed Standard Definitions, Abbreviations and Symbols for Analog Computers referred to by Dr. Mason, the following standards have been developed by the Electronic Computers Committee (IRE Committee 8) and its subcommittees, and have been approved by the IRE Standards Committee:

Standards on Electronic Computers: Definitions of Terms, 1950. 50 IRE 8.S1

Standards on Electronic Computers: Definitions of Terms, 1956. 56 IRE 8.S1

Standards on Static Magnetic Storage: Definitions of Terms, 1959. 59 IRE 8.S1

Another proposed standard, Proposed IRE Standard on Static Magnetic Storage: Methods of Testing Bobbin Cores, 61 IRE 8.3 PS1, has been approved by Committee 8 and submitted to the IRE Standards Committee for approval. Work is presently underway by Subcommittee 8.4 to prepare a new revised glossary of computer terms to reflect changes since the publication of the 1956 Standards.

L. C. Hobbs, Chairman
Electronic Computers Committee,
Institute of Radio Engineers

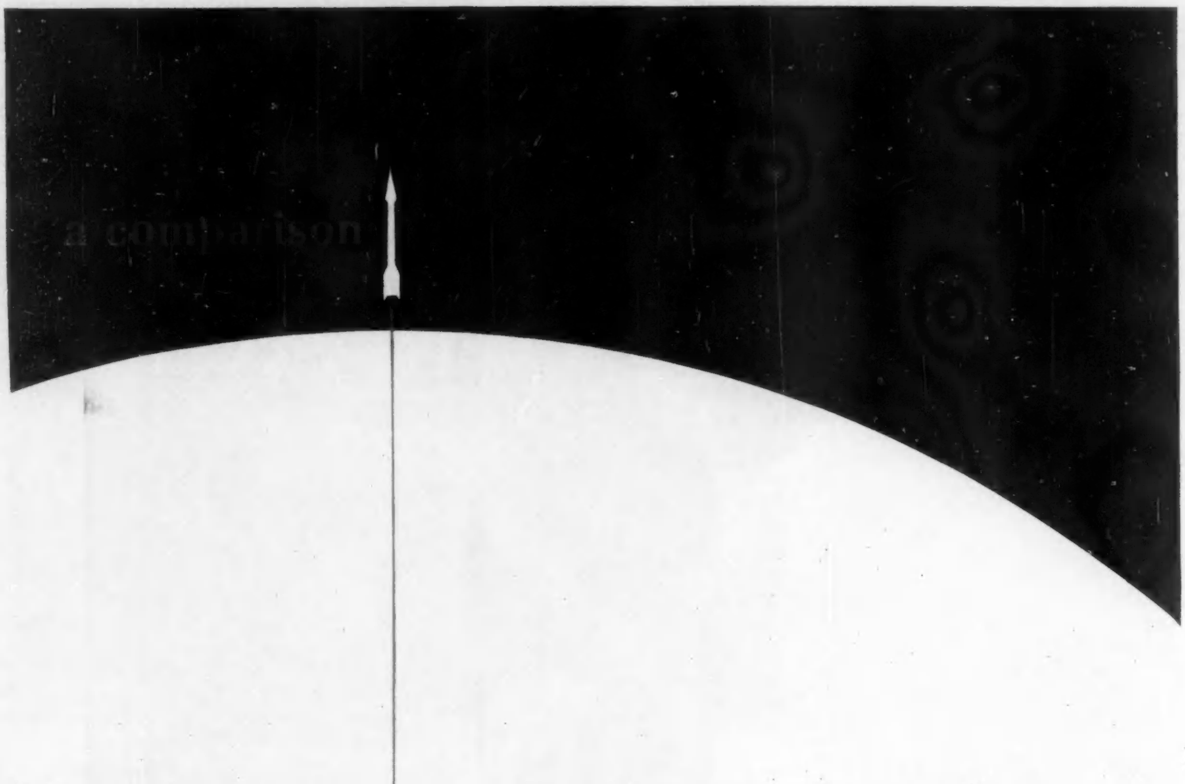
All Things Being Equal

To the Editor—

I would like to point out an error in my article "Predicting and Evaluating the Performance of Analytical Instruments", October '61, p. 93. The equals sign was left out of Equation 19. The correct form is as follows:

$$\mu = \sum_i a_i c_i$$

V. N. Smith
Shell Development Co.



of electromechanical and solid state switching for the aero/space industry. As a manufacturer of both electromechanical rotary switches and solid state devices which are used in a variety of programs, we asked our engineers to compare some of the factors to be weighed when selecting switches and to point out certain benefits of rotary switches. Their replies, summarized below, should be of value to the design engineer.

COMPLEX CIRCUITRY A solid state device is often more practical when the job is relatively simple. For a complex switching function, a rotary switch may be preferred because of its ability to gang on a common shaft and master the whole job with a single component. Ganging of solid state devices, however, presents a delicate circuit balancing problem.

SPEED Where extremely high speed switching is required, electromechanical switches are out of the competition. Average speed of our rotary switches is about 30 steps per second, higher in some special cases.

POWER DRAW Solid state devices normally have a lower control current draw, but this current, although quite small, is required continuously to maintain a load circuit. A solenoid operated switch requires more current, but it draws only for a 10 to 30 millisecond switching period.

For example, our 22P-2T circuit selector or transfer switch is rated at 28 volts, 3.5 amps. Computed energy drawn during the switching cycle is approximately 2.7 watt seconds. But, because of dynamic characteristics of solenoids, the actual energy consumption during a 30 millisecond step is about 1.9 watt seconds. (About as much energy as you need to run a pilot light for three seconds.)

CONTROL & LOAD ISOLATION Load voltage on a rotary switch can be increased without increasing the control voltage. With solid state, if the load is increased, a greater continuous control current is required. Rotary switch control and load circuits are completely isolated.

TEMPERATURE Our rotary switches operate from −55C to 80C, and some are designed for temperatures as high as 135C. Many solid state switches fail at about 70C, and as temperature varies, the circuit characteristics tend to be less stable without additional compensating circuitry.

DEPENDABILITY Usually, solid state circuits are inter-dependent. A fault in one circuit can sometimes cause malfunctions in other parts of the system. Because parts and circuits of a rotary switch are electrically isolated, secondary failures are unlikely.

CONTACT CHARACTERISTICS A rotary switch in closed position has an average resistance of only 10 milliohms; and a solid state switch, in a closed state has an extremely low saturation resistance. However, an "open" solid state switch cannot achieve the infinite resistance of an open mechanical switch.

SWITCHING MEMORY The electrical position of a rotary switch is retained even though a major circuit failure may occur. A minor circuit failure in a solid state switch usually causes the switch to lose its electrical position.

SPACE Where the switching is simple, solid state usually requires less space. However, when multiple or complex switching is required, the rotary type requires less space.

There are other comparisons that might be made, but perhaps the above will aid to some degree in the evaluation of these two methods of switching. For more information on Ledex Rotary Switches that are built to meet space age demands, write or phone Ledex Inc., 123 Webster Street, Dayton 1, Ohio.

LEDEX

Porter Hart
enjoys process control

In a cafeteria at Dow Chemical's Freeport, Tex., plant one day last month, Porter Hart looked around at tables covered with instruments waterlogged by September's Hurricane Carla (CtE, Nov. '61, p. 26). He longed to get back to the business of development. For the past three months, Hart and his process control laboratory has operated at an unaccustomed frenetic pace, repairing and refurbishing damaged instruments, although the plant was rushed back on stream within two weeks of the storm's onslaught. During the hectic post-Carla fortnight, the laboratory had been broken up and the staff assigned in the plant, half working on instrumentation and the other half on switchgear equipment.

Hurricane Carla's flooding stopped temporarily the development and application work that is normally the laboratory's prime interest. Under the calm, relaxed supervision of Porter Hart, who is director, Dow's Texas Div. Process Control Laboratory has been perfecting some new but practical approaches to process control. For example, the laboratory's simulation of a process and its controllers to train operators before a new plant is built has already paid Dow big dividends. In one case the technique spotted an error in design that would have cost the company $100,000 to correct after the plant had been built.

Born with a sense of humor and a need for freedom, Hart gravitated into control work because "it's been fun, and if a person isn't having fun in what he's doing, he's in trouble." He joined the Dow Chemical Co. after graduating from Michigan State University in 1928, with a B.S. degree with a major in physics.

His philosophy was shaped strongly by Dr. J. J. Grebe, then director of Dow's physics laboratory. "Grebe gave a man a lot of freedom," Hart recalls. "I don't want a man working for me if he needs direct supervision."

In building up the process control laboratory, Hart has looked for applicants with varied academic background. He wants a man who can do "a little arithmetic, some algebra, a simple geometry problem or two, and answer a few general science and electronics questions". But he feels a man's educational background is not as important as some other things. He says, "When a man stops being a specialist he becomes useful. And for research work he needs to have a little native curiosity."

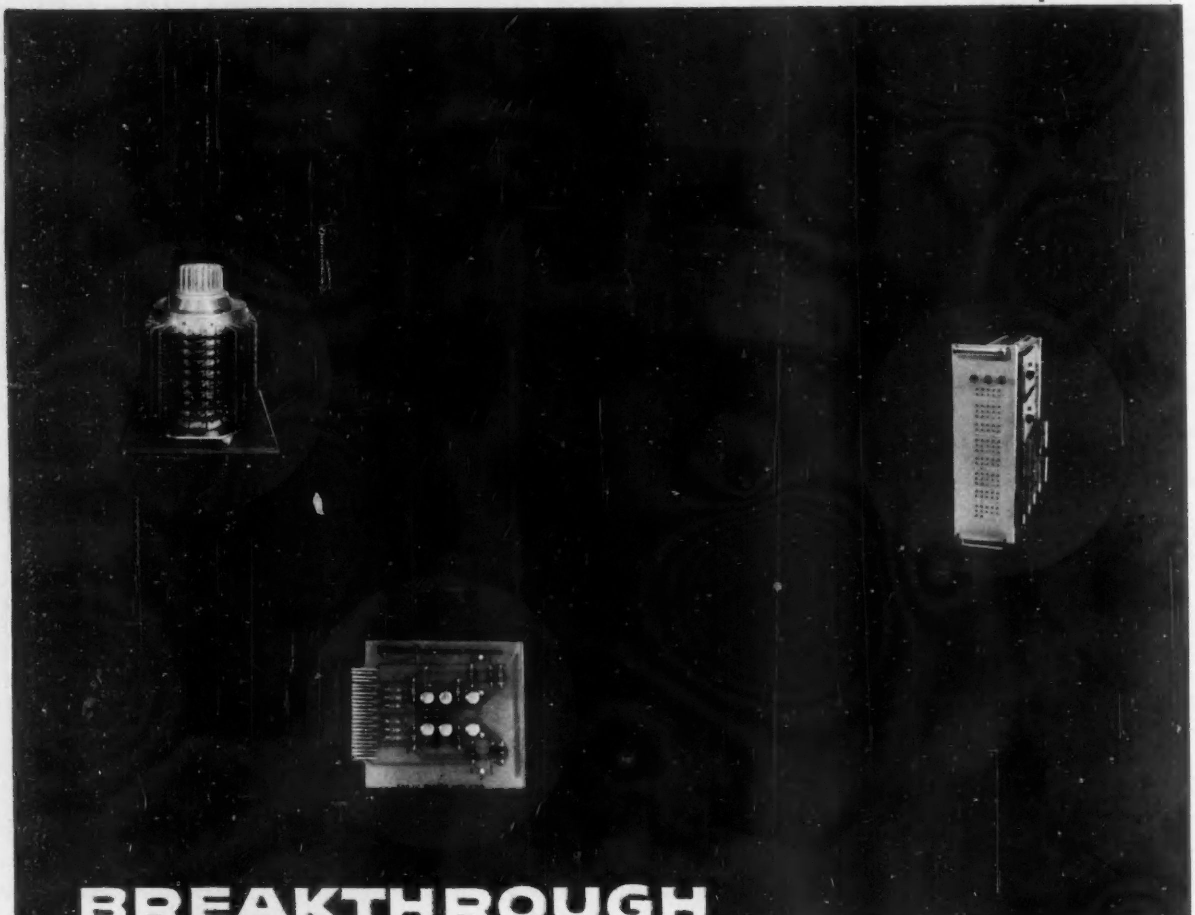
Since he joined Dow Chemical, he has accumulated many patents in instrumentation and control. In addition, he was 1953-54 president of the Instrument Society of America. From 1955 until 1958, he served on the National Research Council. And for four years he was a member of the Texas A&M Steering Committee for Instrumentation Symposia for Process Industries. He is still a member of the Texas A&M Instrumentation Advisory Committee and is on ISA's President's Advisory Board.

Although he has a long string of technical accomplishments behind him, Hart feels the most significant developments are just ahead. He is particularly optimistic about the future of automation planning. He predicts, "In time we will be able to build a mathematical model of a new plant, run it from simulation, and continuously feed the results into a digital computer which will calculate the economics and optimize the process.

"With such a setup, we'll be able to design plants run by both analog and digital computers, applying each type where it is best suited."

Looking even further into the future, Hart foresees the day when a central station will replace the chemical plant's control rooms, operating as many as six different plants. "Only two men will be needed to run such a complex," he says, "one manning the displays, and the other patrolling the facility to check on physical conditions."

"Maybe the central should be right at the main gate instead of inside," he adds, with a twinkle in his eye. "That way the plant manager can see how his plant is running too, at least twice a day."



Newsbreaks In Control

ASD Drops Plan to Buy NC Package

Dayton—Aeronautical Systems Div. of the U.S. Air Force has shelved its plan to buy about 40 numerical control systems in one package to replace controls already installed on Cincinnati Milling Machine Co. tools. When the agency requested bids only one supplier prepared a firm proposal and ASD considered it far too high. Now the Air Force will ask each contractor to replace the controls on tools each operates for the Air Force.

University To Set Up Information Systems Center

Cambridge—In January Harvard University will announce the establishment of an interdisciplinary information center for the university to conduct research into all phases of data processing and advanced system automation. Reason for the new facility: recognition that the computer is affecting across-the-board operations of industry—engineering, production and management—and all functions are being related more closely by information technology.

Controversial Beacon Report Released

Washington—Federal Aviation Agency has finally released the controversial Project Beacon report, a study made by outside consultants to evaluate how FAA has been using technology. The agency has already set up a group to implement the report's findings on radar and beaconry. One area still in doubt, however, is automatic data processing. The Project Beacon specialists were not impressed by FAA's Data Processing Central; instead they recommended a new control system that would take five years to develop and cost $500,000,000. There is no word yet on how FAA will implement this recommendation.

Russian Computer-Control Experiment

Moscow—For forty eight hours, Soviet engineers ran a soda plant at Slavyansk in the Donets Basin by a computer located at Kiev, 630 Kilometers (390 miles) away. Computer is said to have calculated most economic operation of the complex, transmitted controller commands by wire to run the plant remotely. Russians claim the test was the first automatic operation of a soda plant.

European Countries Plan Joint Space Program

London—Nine European nations have provisionally approved a European commercial and scientific space plan. First big project: to launch a satellite test vehicle from Woomera, Australia in 1965. The first vehicle, a three-stage unit, will be truly European: its first stage will be the British Blue Streak missile; its second, the French Veronique; and its third stage will be developed by West Germany.

Taking the Art Out of Papermaking

Papermakers are eyeing computer control of their ancient process. Lack of process knowledge and of proper instrumentation have been stumbling blocks, but research is underway to uncover the secrets of papermaking.

WASHINGTON, D.C.—

"They're trying to take the 'art' out of papermaking!" exclaimed a surprised paper industry engineer after listening to a morning full of presentations on how to use digital computers to control a paper mill. "Not all of these computer people know what they're doing," said another, "but it's about time we had something new to control papermaking."

These comments are typical of the reaction of paper mill engineers to computer control. After earning a reputation as a stodgy, old-fashioned industry, the paper industry has bloomed in new garb. In September papermakers saw the first computer go on line at an Idaho mill. Last month a southern mill announced that it had bought the industry's second control computer. And industry rumors say that as many as a half dozen more have been sold.

These developments mark a radical change in thinking in the paper industry. For years instrument industry spokesmen have complained that paper mills were badly underinstrumented. And in recent years the papermakers have been plagued with tremendous overcapacity. Just last year, demand started to catch up with capacity, and now the papermakers are planning expansion.

What's involved in computer control was one of the main topics of conversation when technically minded paper men got together at the Washington meeting, the 16th Engineering Conference of the Technical Association of the Pulp and Paper Industry (TAPPI). Two problems were foremost: 1) a need to explain what happens in the papermaking process, which has always been tricky and somewhat unpredictable (see box), and 2) a need to develop instruments to make the kind of measurements computer control requires.

• **On the latch**—Potlatch Forests, Inc. unlocked the door to the first control computer in the paper business when it ordered an IBM machine last May. Dwain M. Bates of PFI told the TAPPI computer control session that the IBM 1710 system at the 650 ton/day bleached kraft paperboard mill in Lewiston, Idaho, operates on stream, but open loop. In one phase, the machine serves as a data logger. Analog inputs from pneumatic instruments—measuring 41 variables, such as 15 flows to and from the fourdrinier, speed, slice opening, headbox level, wire pit temperature, and freeness—are converted first to current signals and then to digital pulses for entry into the computer.

A log sheet is produced every 10 min during a run, with any off-limits signals being printed out in red. Some variables need computation, for example, headbox consistency, slice velocity, water removed, and daily production rates.

Since they did not have sufficient technical knowledge of the process on the fourdrinier, PFI and IBM were not able to use physical, hydrodynamic, or chemical analyses to design the mathematical model for the computer. Instead, they worked with historical data of quality results on the PFI machine, statistically analyzed them, and constructed programs for the most run paper grades.

PFI hopes to net at least $600,000 by cutting downtime alone.

• **A bigger step**—At Potlatch's mill, the computer tends only the paper machine. Another paper company has bigger plans. Southern Land is moving closer to true computing-control at its new 700 ton/day kraft linerboard mill in Cedar Springs, Ga. Although the GE 312 will not have closed-loop control as a prime function at first, some control outputs—probably for the refiners—will be generated, with more to come later. And the computer will be the nerve center of control of the entire mill.

The mill, scheduled to go on line in about a year, has been designed from the ground up to take advantage of computer control. Cooperating with Southern Land and GE are J. E. Sirrine Co., a consulting engineering group, and Beloit Iron Works, which will build the papermaking machinery. The Foxboro Co. will supply electronic instruments.

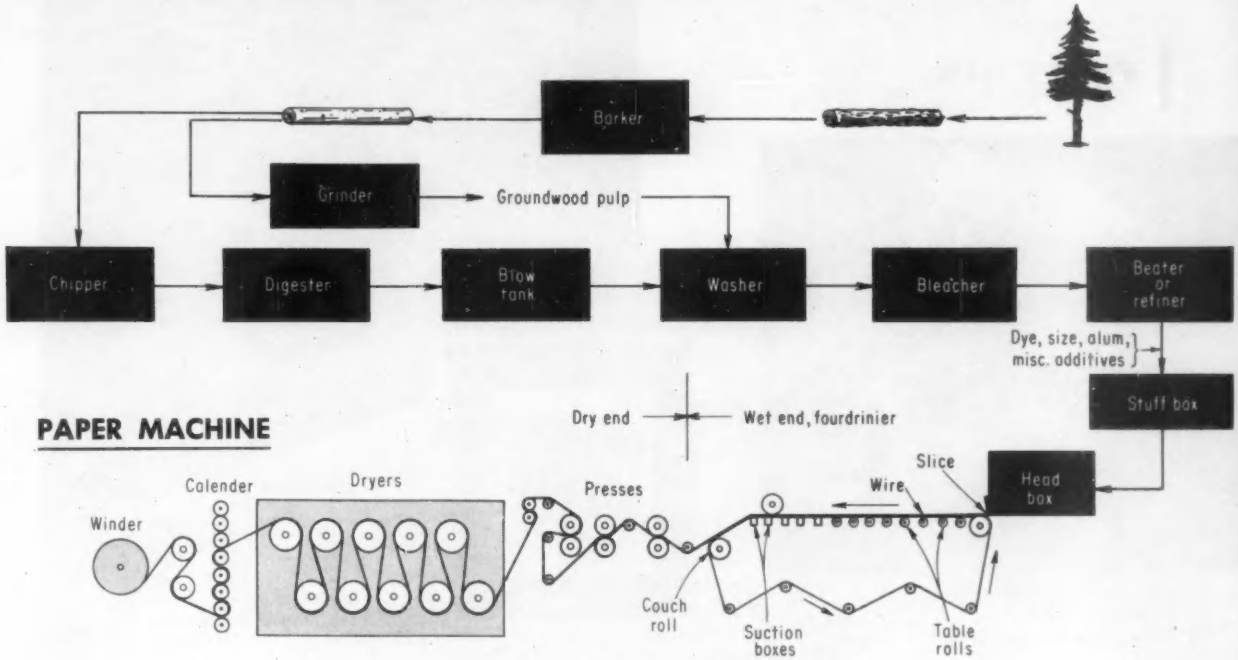
Southern Land will get a lot of data from its computer. About 450 points will be logged on typewriters and punched tape: the former for mill operators who are concerned with current operation and the latter for analysis off line. The machine will print out operating guides for plant men and alarm when off-limits conditions occur. For management, the computer operation will correlate variations in process functions with operating conditions.

• **Understanding the process**—Underscoring the need for more process knowledge and for new instrumentation is a joint project announced by IBM and The Institute of Paper Chemistry (Appleton, Wis.) to investigate and define the basic processes involved in making one major (and unnamed) paper product. The project started at the Institute in May; it will take advantage of that group's knowledge of the relationship of fibers to end-product quality. IBM will investigate papermaking process dynamics with the object of designing new instrumentation systems.

The project will evolve in three stages: engineering analysis, determination of relationships, and specification of instrumentation. IBM hopes that before the last stage, paper companies will become interested in helping back the program and that instrument manufacturers will also assume some of the development.

• **Instrument lag**—This research project underscores a basic truism in the paper industry: most paper mills suffer from two "instrumentation gaps". First—and this is the easiest to bridge—new instruments (or variations on standard ones) need to be developed to measure variables in the process that are understood well enough to be measured. The second gap involves the lack of knowledge of the basic processes of papermaking.

One computer salesman, for instance, says that 80-90 percent of all paper mills have inadequate instrumentation. Although he tells potential buyers that they can expect a 5



A Papermaking Primer

Of the five main paper types—tissue, printing papers, corrugating media, linerboard, and newsprint—linerboard claims the largest production in the U. S., in terms of tons produced annually. In all of North America, though, newsprint is the biggest product, since Canada supplies half the world's needs for this paper, including 75 percent of the U. S.'s newsprint. About 80 percent of newsprint is made from groundwood fiber—cellulose fibers separated from lignin, the wood's binding agent, by grinding barked logs of softwoods.

Other papers are made from pulp produced by digesting wood chemically. In the kraft process, chips cut from barked logs are pulped in a sodium sulfate liquor (so it is also known as the sulfate process). Another alkaline pulping process uses sodium carbonate to make soda pulp. And an acid process uses sodium sulfite to make the digesting liquor. After pulping, the delignified chip mixture is blown into a tank, where the chips are smashed against a hard target to release the cellulose fibers.

The fiber slurry from these tanks (or the ground fiber mixture in a groundwood process) is then washed and bleached before being beaten for strength, or refined. After the required dyes, sizing, and other additives are injected, the pulp mixture (about 97-percent water) is ready for the paper machine. An important measure of the pulp slurry is freeness, the ease with which water drains from the mixture.

Paper is formed on the paper machine, called the fourdrinier, by laying out the pulp mixture on a moving, shaking wire, causing the fibers to become aligned perpendicular to the machine direction. In the "stuff box", the mixture is watered down to about 0.5-percent consistency by the addition of "whitewater" (reclaimed water with tiny pulp fibers). From here the pulp passes to the headbox which maintains a uniform fiber suspension. The pulp is let out onto the wire in the right amount by the "slice". The wire of the fourdrinier is driven by the "couch roll" and supported by suction boxes and table rolls; the latter promote drainage by breaking the surface tension. The sheet is carried on a moving felt through the next two stages in which presses compact the fibers and remove water from the 80-percent water sheet to make it 60 to 70-percent water, and dryers reduce moisture to 6-percent before the paper is fed to the calender stacks. The paper is then wound on reels.

---

to 6-percent increase in efficiency by installing a control computer, he sees a 15 to 20-percent increase by merely modernizing instrumentation.

Outsiders have noticed that the first companies to take the plunge in computer control have been new ones. Potlatch, for example, is only 11 years old, and Southern Land is a brand new firm, building its first mill. In the past, papermakers have sometimes been unwilling to pay the cost of sophisticated instrumentation, and instrument companies have not felt the market big enough to make development work pay off.

• **On-line analysis**—As an example of an instrumentation-analysis problem, Dr. Edward F. Thode, administrator of the Engineering and Technology Section of The Institute of Paper Chemistry, pointed to the kraft pulping process as a ripe field for instrument development. Manufacturers need to know what is happening during the kraft "cook" to analyze the chips. Rather than remove samples of chips from the digester, Dr. Thode suggests that papermakers analyze the liquor and tie its analysis to the condition of the chips. This, he suggests, is a relatively simple problem: although some elements of understanding are missing, paper chemists at least know what's needed.

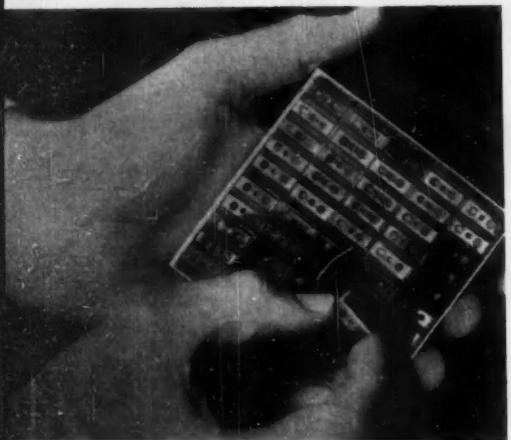
But it is an exception. Dr. Thode feels that clear definitions of most problems do not exist. For instance, to control the papermaking process to produce a specific type of paper, papermakers first have to learn how changes throughout the process—from the woodlands to the calenders—affect the end result.

To help untangle the complicated papermaking process, 30 member companies of the Institute are supporting work in analysis of alkaline pulping liquors. Another project, supported by 50 paper companies, has led to the development of a commercially available instrument for determining the drainage properties of papermaking fibers.

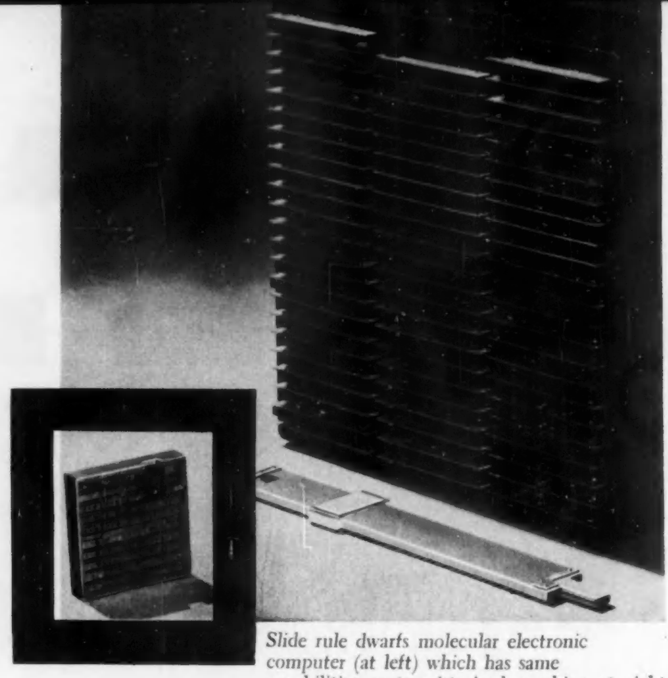
For an example of advanced speed, control on a paper machine, see page 71.

Meanwhile, computer makers are hard at work selling control systems to papermakers. Many are listening receptively, but there is a critical need for measuring devices.

—Stephen S. Livers



Closeup shows how tiny modules are inserted to buildup molecular electronic computer.



Slide rule dwarfs molecular electronic computer (at left) which has same capabilities as transistorized machine at right.

Startling Computer Midget

Texas Instruments demonstrates the first general purpose digital computer made with molecular electronic components. The tiny machine weighs only 10 ounces and is a shade bigger than a pack of cigarettes.

DAYTON—

A general purpose digital computer the size of a pack of cigarettes was demonstrated last month for the Aeronautical Systems Div., U. S. Air Force. The device, built by Texas Instruments Inc. to show technical feasibility, was programmed to simulate a desk calculator. It could add, subtract, multiply, divide, and calculate square root.

Demonstration of the device was rumored to have been set up by the Air Force to convince some electronics industry skeptics that molecular electronic (or functional electronic block) equipment was closer to wide acceptance than they had realized. If that were the intent, the demonstration succeeded better than planned.

As Control Engineering went to press, the semiconductor industry was ready to break open like a melon. Almost every supplier of semiconductor devices—transistors and diodes—was promising commercial availability of one-piece devices such as flip-flops AND, OR, NAND, and NOR units by the first quarter of 1962. Some of those who were now making the greatest haste had told CtE editors only a month before that they would not make such molecular devices available until 1964 or 1965.

Texas Instruments, Westinghouse and Fairchild Semiconductors already have a line of functional one-piece semiconductor devices. Texas Instruments new series 51 is described on page 146. But now rushing plans to have commercial availability early in 1962 are Motorola, Transitron, and General Instrument Companies.

TI's molecular computer weighs only 10 ounces; it is made of 587 functional blocks. The TI machine performs exactly as the digital computer shown with it above, the bigger machine weighs 480 ounces, has a volume of 1,000 cubic inches, and is composed of 8,500 conventional components. For demonstration purposes, TI did not try for an ultra sophisticated computer design. The demonstrator was a serial, binary, fixed-point machine with an operand word length of 10 bits, plus sign. It uses synchronous logic, timed from an internal 100-kilocycle clock. Total power: 16 watts.

Three types of molecular electronic units were used. They are: flip-flops, NOR gates, and logic drivers. Eight to sixteen of these units, each smaller than a dime, were connected into a computer module and encapsulated. Forty-seven such modules make up the complete computer.

To speed up completion of the demonstration machine, TI incorporated only one functional unit in the basic building block of the machine. In the future, the company plans to combine units so that two, five, or maybe even 10 flip-flops would be incorporated in the basic unit.

One area of work that still needs attention is connections. Individual flip-flops, logic units, or drivers are still soldered together, although the typical functional unit eliminates a lot of soldering between components.

The Air Force has had two major contractors in its molecular electronic work: TI and Westinghouse Electric Corp. TI has followed, at Air Force request, a digital path and concentrated on product application. Westinghouse has been doing more basic research and has followed an analog line, again at Air Force urging. An Air Force spokesman thought "Westinghouse was close to being ready to demonstrate its analog device".

NEW DUCTILE IRON DIAPHRAGM CONTROL VALVES ARE TOUGH AS STEEL, BUT LOWER IN COST

K&M control valves made of ductile iron can save you a lot of price/performance juggling. Stronger than steel valves, harder than steel valves, they cost about 15% less. You can use them in processes where cast steel used to be an absolute must—applications calling for temperatures from −20°F to 650°F and pressures up to 1,000 psig.

Ductile iron, a metallurgist's pipe dream just a few years ago, makes castings that are as pressure tight as steel and as corrosion-resistant as gray iron. The castings have a better surface finish than steel and are easier to machine; inner contours are smoother, less subject to erosion. Ductile iron is strong enough (tensile strength—70,000 psi, yield strength—50,000 psi) and hard enough (160 Brinnell) that we even recommend its use in K&M split-body valves—formerly made only with steel bodies.

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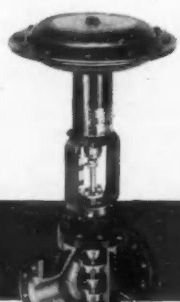

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CIRCLE 23 ON READER SERVICE CARD

Living Organisms Generate Electric Power

LOS ANGELES—

A radical new source of electric power has been demonstrated here: as bacteria consume natural minerals and organic matter, they produce an electric potential between the poles of a battery. The device, built by Magna Products, generates sufficient power to operate radio beacons, signal lights, or other apparatus at sea. In Magna's laboratories, the device has run for more than a year.

This generator is just one of three so-called "bio-power" devices that Magna has built. All were conceived by the company's president, Dr. Gilson H. Rohrback. The other two: a cell that operates on organic matter and air, and one that runs on the photosynthetic organisms that convert solar energy directly into electricity.

Rohrback says a variety of materials could be used for fuel in these new devices: sugar, potatoes, or even raw sewage. The only limitation is finding a bacteria that can live on the compound chosen as fuel.

New Dataphone Ups Transmission Speed

NEW YORK—

American Telephone and Telegraph Co. is field testing a new model of Dataphone that can transmit at rates up to 2,000 bits per sec., almost twice the speed of the currently available Dataphone. Units built in the model shop at Bell Telephone Laboratories have been installed at such users as the Social Security Agency, Prudential Insurance, and Radio Corporation of America for testing and evaluation.

The new Dataphone operates on phase modulation. Although it accepts and delivers serial data, its quaternary or four-phase nature permits sending two bits at a time. Another innovation is an internal feature for synchronous operation. The transmitter portion has a self-contained clock and the receiver portion maintains continuous bit synchronization for all data-signal sequences.

AT&T has not yet filed rates for the new system. Actually, two versions are being tested. One operates at a rate of 2,000 bits per sec., but the other runs at a higher rate, 2,400 bits per sec.

AIEE-IRE Consider Marriage To Form Biggest Society

NEW YORK—

First steps to effect a merger of the two largest engineering societies in the world were started here last month. A committee has been formed to determine the feasibility and form of a consolidation between the American Institute of Electrical Engineers and the Institute of Radio Engineers.

IRE brings to the prospective merger a membership of 91,000; AIEE has 70,000 members. The proposed new society would be international in scope with a total membership of over 150,000 (there is some duplication of membership now).

The committee has been instructed to have its report ready for each society's board of directors by February 15, 1962. If merger looks feasible, the members of each society will vote and, if they approve, consolidation will be completed by January 1963.

Ancient arithmetic, invented by the Chinese and called modular arithmetic, speeds up computer operations 20 times. Because numbers are not carried over, calculations run as fast as the computer can operate. Modular arithmetic is good for addition and subtraction and is particularly effective in multiplication. But it has no advantage in division. Scientists at Lockheed Missiles and Space Co. are updating the ancient subject to speed the design of computer circuits.

•

An engine without an ignition system has been developed for space applications such as stabilization control and guidance. It was developed jointly by Moog Servo-Controls, Inc. and Marquardt Corp. When liquid fuel combines with an oxidizer it ignites spontaneously providing thrust which can be varied depending on the mixture. Complete name of the unit: a variable thrust hypergolic engine.

•

Computer control of rocket engine static tests is underway at the Naval Propellant Plant at Indian Head, Md. Navy uses an RCA 501 general purpose computer first to run countdown before firing and then to collect test data and analyze performance of the engine. Transducer calibrations are stored on tape and any one of 128 can be called out by the test operator.

•

Engineering students at the University of Texas will start learning computer programming and operation in the freshman year after next fall. Computer knowhow, says the faculty, is now essential for homework and research problems.

•

Electronic controls have been installed at a ready-mix concrete plant, the first such installation in the United States. At the Foxon Concrete Co., the new controls automatically operate the batching of the mix and dumping of the ingredients. An operator chooses the desired one of ten possible mixes by pushing a button. Supplier: The Noble Co., Oakland, Calif.

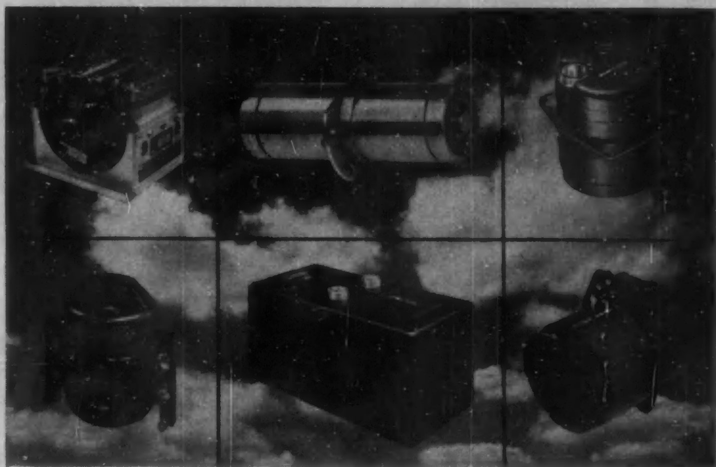
•

Robot measuring stations are being placed in Lake Michigan to help locate the movement of pollution in the waters off Chicago. On call from a master station, the units will measure depths at three levels, store them on a magnetic medium, then transmit the data back to the master station. The U.S. Corps of Engineers built the device, eventually will place 25 to 30 of the robots in the lake.

FROM: *Bendix Eclipse-Pioneer*

SUBJECT: *Aerospace gyros, synchros*

SIX LIGHT, RUGGED BENDIX GYRO TYPES MEET BROAD AEROSPACE NEEDS. With the Bendix gyro line, you enjoy a *double* benefit. First, *the line is unusually versatile*—includes models for a wide range of applications, such as radar stabilization systems, aircraft and missile guidance and control systems, bombing and navigational systems, and many others. Second, *high quality of manufacture is consistently combined with such advantages as light weight, proved accuracy, reliability, and ruggedness.*



Top: vertical; rate; and directional gyros. Bottom: free-cageable; two-gyro, three-axis (contains both vertical and directional units in a single package); and free-uncageable.

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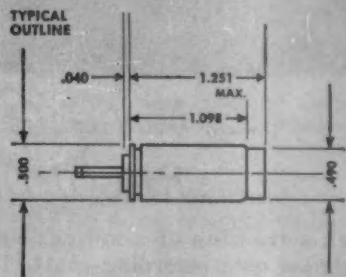

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Accuracy................±15 minutes

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THE Bendix CORPORATION

WHAT'S NEW

Computer Conclaves

- Standards Conference Eyes Data Processing
- Systems Meeting Airs Business Problems

Standards Soon for Computers

HOUSTON—

Computer systems have been too new to impose standards on them. But they are rapidly coming of age and standardization is not too far away. That's the conclusion visitors to the National Conference on Standards of the American Standards Association reached. In fact, 1962 is likely to see a lot of proposals for computer standards circulate among manufacturers and users.

►Item. Users want a standard character code to make communications between systems of different manufacturers easier—without an expensive translation step. The U.S. government, which has computer systems made by many manufacturers, is urging the adoption of such a standard within two years.

►Item. By the first part of 1962, a task force will have firmed up recommendations for a standard numeric font for optical character recognition. Suggestions have already been pared to two sizes of type. In one, each character is 0.056 in. wide and 0.094 in. high; in the other, the character is 0.056 in. wide but 0.140 in. high. A likely compromise: a type character 0.056 in. wide and 0.112 in. high. Once the standard for a numeric font is proposed, work will start on developing a standard alphanumeric font.

►Item. Within the next few weeks, a single, seven-bit, dense binary code, with subsets and a superset to meet the varied demands of data processing, will be submitted to industry for comment and review.

Probably the strongest force behind the standardization movement is the government, with its tremendous investment in computers. Even so, standardization is likely to win slow acceptance. For example, a change from the 80-column punched card system would affect an estimated $1.25 billion worth of data processing equipment already installed.

Management Role for Data Processing

CLEVELAND—

When electronic data processing first moved into business five years ago, the business data computer was likely to end up under the supervision of the company controller or the accounting department. That was because the computer was usually installed to do accounting jobs or record keeping. Today, the computer is becoming more and more a management tool. And the data processing department is becoming an adjunct of top management.

That's what more than 1,100 persons heard at the 1961 international Systems Meeting, sponsored by the Systems and Procedures Association. As data processing operations are spreading out, affecting the operations of many departments, the man emerging as the most important figure is the systems and procedures specialist. And the International Systems Meeting is fast becoming his platform for airing problems introduced by putting the digital computer on line in business operations.

At this year's meeting, the spread of attendance was imposing: listeners came from top management, auditing, and accounting, from manufacturing and production control, and from data processing management and programming. Every industry, from chemicals and food to aircraft and banking, was represented.

The computer's new role in business was the subject of two important presentations: "The Management Implication of a Total Information System", and "The Changing Role of Systems to Create Management Information". Backing up this theme were nine other sessions on specialized topics and 30 two-day seminars that attacked specific problems such as developments in optical scanning, data collection and communications, computer comparison and evaluation, and inventory control.

Control Makers Trod Hazardous Tightrope During Berlin Crisis

Control companies expect to stay in West Berlin. It is business as usual on the surface, but behind the scenes are plans for any emergency.

WEST BERLIN—

In beleaguered West Berlin, 28 control makers give the impression of "business as usual". To an observer of the production scene, the Communist sealing of the border between east and west sectors of Berlin has had no effect on the city's $40 million a year control industry. But beneath the calm facade, the control companies have made careful plans to protect designs and production potential if the Communists force an evacuation of Berlin.

Many executives are counting on a firm Western stand to prevent such retreat. They point out that West Berlin has enjoyed an economic boom over the past four years despite almost continual political crises. Total production, for example, has tripled during the past ten years. This year value of production should top $3 billion. Twenty-five percent of the output is consumed right in West Berlin, 60 percent is exported to West Germany, and 14 percent goes to other foreign countries. Only one percent is consumed in East Germany.

Thus East Germany exerts little influence as a customer or, as it turns out, as a supplier of labor for West Berlin control companies. Of the 11,000 people employed in control plants in the Western sector in Berlin, only seven percent lived in the Communist section of the city.

• **Preventing infiltration**—Loss of this working force when the Communists sealed off East Berlin has not appreciably hurt West Berlin companies because most organizations had already taken some stringent security procedures. For example, some companies never placed an East Berliner in a position close to a research and development group. Others were even stricter, would never place an East Berliner in any position where he would have access to information the company would not want leaked.

Since the Berlin crises started in 1958, control companies have spotted an occasional Communist agent who had been planted on the payroll to work into a position of responsibility where there was access to valuable engineering information. One company discovered what was happening the hard way when an East German company produced an identical copy of one of its most promising new products before the designing company in West Berlin had even put the device into production.

There has been no retreat by control companies or by Berlin workers since the Communists started acting tough. Such industrial giants as A.E.G., Siemens, and Telefunken have maintained their heavy investments in the city, although, at the same time, they have been enlarging their plant facilities elsewhere in Western Germany. These new facilities both serve as an emergency haven—if Berlin should be lost to the Communists—and replace plants built before 1942 in what is now the Eastern sector of the city.

• **Alternate plans**—Although the companies outwardly appear confident they are in West Berlin to stay, most have taken some precautionary measures in case they don't. Some companies have microfilmed their blueprints and other important paperwork and deposited the films with West German banks. With such information, they expect to be able to start over if they are chased out of Berlin. Others have established massive spare parts depots in safe sections of Germany so they will be able to service customers no matter what happens. A few companies have even deposited duplicate jigs, tools, and production machinery on the safe side of the Communists new iron curtain.

Apparently design and production potential is well in hand for any emergency. What worries control makers most, however, is where they would get skilled personnel if they have to start over. One company has gone so far as to set up a secret alternate location. It has prepared sealed instructions which are kept under lock

and key and will be distributed to employees if real trouble starts in Berlin. The instructions ask the workers to escape and find their way to the company's Shangri La.

One thing most control companies have tried to do is gradually shift their research and development work and move it west. Even though they had strict security, they feel the Communists are too close for comfort. An exception has been A.E.G. which still supports large instrumentation research and its main Institute for Automation in Berlin. As a safeguard, A.E.G. parallels work at these two organizations in smaller subsidiary institutes in the west.

—J. Morrison
McGraw-Hill World News

Numerical Control Emerges at European Show

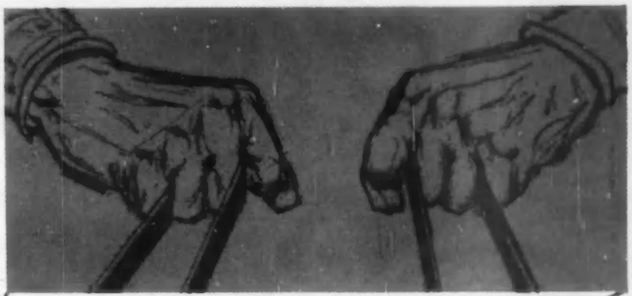
BRUSSELS—

European machine tool builders are leaning towards numerical control of machine tools. If their customers approve, the builders will go all out. That sums up the feeling expressed at the Seventh European Machine Tool Exhibition, held in September. With 4,000 machines displayed by 766 manufacturers – who produce about 40 percent of the world's supply of machine tools—the show was the biggest ever held.

Although the 40 or so numerical controlled tools on display represented a tiny portion of the total machines at the show, the threefold increase in numbers over the 1959 show was significant. Practically all of those at the Brussels exhibit were positioning controls—for millers, drillers, center and turret lathes, or horizontal and jig borers.

• **Contrast with U. S.**—European designs apparently contrast sharply with American ones. In Europe, U. S. visitors noted, plugboard programming is more popular than punched tape, the U. S. favorite. European systems tend to be cruder in concept but rely on more sophisticated components than do U. S. systems.

For example, most European manufacturers favor optical pickoffs, with Moire fringes, over mechanical methods. Two approaches are used most often. In one, all-digital equipment attains the proper accuracy with fine pitch gratings. In the other, analog interpretation is combined with digital counting for position accuracy with less expensive coarse gratings.



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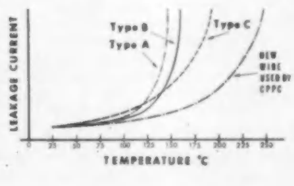

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CLIFTON PRECISION PRODUCTS CO., INC.
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CIRCLE 31 ON READER SERVICE CARD

Instrument Makers Gird to Meet Booming User Spending

As user companies make plans for what may be the second biggest year for capital spending in U.S. history, instrument makers are set to expand at an even greater rate to keep up with new control demands.

U.S. business is getting set for a near record period of capital investment. According to a survey conducted by McGraw-Hill Publishing Co.'s Dept. of Economics, companies are now making plans to spend 4 percent more on new plants and equipment than they did this year. And instrument companies, anticipating increased demand ahead, expect to boost their spending by 18 percent, the greatest jump by an industry group.

In October, when the survey was conducted, businessmen expected 1962 capital spending to total at least $35.84 billion. This would be second only to 1957 as a record year for the capital goods industries. Manufacturers, who account for fully 40 percent of all capital investment, have scheduled a 7 percent increase over 1961's spending level.

The table below gives the results of the survey. Note that the figures given do not add to give the total for all business, since segments of the economy outside the direct interest of the control field have been omitted from the tabulation, but they have been added into the total.

Already business plans to spend more in 1963 than it spent this year. Manufacturers, for their part, plan a 4 percent increase over 1961. These early plans are of course subject to change. Even next year's spending plans will change, but experience has shown that, barring major upsets in the business picture, these plans usually are revised upward.

- **Inflation's chunk**–Expectations of increased prices for new plants and capital equipment were also surveyed in the study. On the average, companies looked for a 2.6 percent increase in the prices they would have to pay. This means that a good part of the planned spending increase is due to price rises. Machinery manufacturers expect the largest price boost,

BUSINESS' CAPITAL SPENDING PLANS

INDUSTRY	1960 Actual*	1961 Estimated	1962 Planned	1963 Planned	1961–1962 Percent Change
	(Billions of Dollars)				
Iron and Steel	$1.60	$1.16	$1.33	$1.21	+15
Nonferrous metals	.31	.26	.28	.35	+ 7
Machinery	1.10	1.10	1.17	1.17	+ 6
Electrical Machinery	.68	.68	.62	.63	− 9
Autos, Trucks, & Parts	.89	.68	.70	.74	+ 3
Transportation Equipment (aircraft, ships, RR eqpt.)	.42	.39	.42	.36	+ 7
Fabricated Metals & Instruments	.95	.90	1.06	.99	+18
Chemicals	1.60	1.65	1.62	1.57	− 2
Paper & Pulp	.75	.72	.76	.77	+ 6
Rubber	.23	.22	.24	.26	+11
Stone, Clay, & Glass	.62	.49	.53	.53	+ 8
Petroleum & Coal Products	2.64	2.78	3.06	2.94	+10
Food & Beverages	.92	.98	1.04	.93	+ 6
Textiles	.53	.51	.56	.53	+10
Miscellaneous Manufacturing	1.24	1.17	1.20	1.21	+ 3
ALL MANUFACTURING	14.48	13.69	14.59	14.19	+ 7
Electric and Gas Utilities	5.68	5.75	5.87	5.97	+ 2
Commercial**	8.44	8.38	8.72	7.85	+ 4
ALL BUSINESS	35.69	34.46	35.84	34.49	+ 4

** U. S. Dept. of Commerce, Securities and Exchange Commission, McGraw-Hill Dept. of Economics*

*** Figure based on large chain, mail order, and department stores; insurance companies; banks; and other commercial businesses*


SKINNER provides
custom flexibility
in standard
solenoid valves
SKINNER ELECTRIC VALVES
OUT
CYL.
IN
UL

Versatile, top quality V5, X5 line offers wide range of options

Skinner's two-way and three-way V5, X5 series of solenoid valves has earned the description—"The Universal Line." With more than 100,000 variations possible, V5, X5 valves are available for every conceivable application. And top quality is emphasized with bubbletight sealing, and stainless steel body, plunger and sleeve assembly. Precision machining, unique welding techniques, specially designed and developed machinery and manufacturing methods are all used by Skinner to produce the best valves made. These valves are small, yet handle operating pressures as high as 3000 psi. They accommodate all media that do not corrode stainless steel. And no other solenoid valves offer so many optional features. Check the following options.

FLOW CONTROL

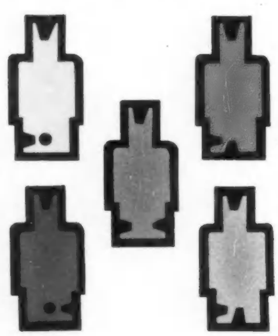
Precise, accurate control of media flow is possible with all Skinner V5, X5 valves. Both two-way and three-way valves are available with adjustable flow in the main stream, and with manual override. Two-way valves are also available with adjustable bypass. Exhaust flow can be controlled in three-way valves.

ELECTRICAL HOUSINGS

Skinner offers an electrical housing for any application. Some of the most common are:

- standard ½″ NPT conduit
- grommet outlet
- single or double automotive terminals
- JIC housings with integral junction box
- AN connector for military applications
- strain relief connector for quick disconnect

All housings are steel, plated for wear and appearance, and can be rotated 360° for easy installation.



PORTING

Restrictions of installation or application, and mounting are minimized because Skinner provides a wide variety of port location options. V5, X5 valves are available with ports at right or left angles, on bottom, top, and sides for virtually all combinations of flow.

MOUNTING

Skinner V5, X5 valves are provided with tapped holes for normal mounting, with mounting brackets for panel or other surface, or with flange for direct mounting without threaded pipe connections.

The Skinner V5, X5 series of two-way and three-way solenoid valves provides top quality design with orifices from 1/32″ to 3/8″ diameter, normally open, normally closed, dual purpose, directional control and multi-purpose, in standard and explosion-proof construction. Also included in this line is a three-way quick-exhaust type which is designed with an additional port to exhaust cylinders 4 times faster than standard types.

COILS

Skinner V5, X5 valves are available with coils of many types for most DC and AC voltages at 25, 50 and 60 cycle frequencies. Whether your requirements are for continuous or intermittent performance, in tropical, high moisture or high temperature environments, or for dual voltage, Skinner UL approved coils are available with leads of several types and lengths.

• • •

Typical applications—machine tools, cylinder control, instrumentation and automation of all kinds, laundry equipment, aircraft and missiles, etc. For catalogs and complete information contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

When you specify solenoid valves, specify Skinner. Skinner solenoid valves are distributed internationally.

SKINNER ELECTRIC VALVES

THE CREST OF QUALITY

SKINNER ELECTRIC VALVE DIVISION,
THE SKINNER CHUCK COMPANY • NEW BRITAIN, CONNECTICUT, U.S.A.

PRINTED IN U.S.A.

averaging 4.5 percent.

Steel producers' spending plans are particularly interesting to instrument and control makers because these companies have slated a 15-percent increase next year, despite considerable excess capacity (mills were operating at 74 percent of capacity in September vs the preferred rate of 98 percent). This growing investment level points up the industry's continued interest in modernizing facilities and cutting production costs through the use of more sophisticated control systems.

Low Cost N. C. Debuts

Simplified design and large scale production brings the cost of a new point-to-point numerical control system down to about $4,500.

WEST HARTFORD, CONN.—Production line manufacturing, with cost savings by numerical control and a new approach to structural design are behind a new low cost numerical control system, announced last month by Pratt & Whitney Co. Since the company has placed a $8,595 price tag on a numerically-controlled drill press (called the Tape-O-Matic Drill), experts estimate the numerical control system costs about $4,500. That makes it probably the least expensive numerical control system currently on the market.

P&W, gambling on wide acceptance of its new system and large orders, has set up some Detroit-style production facilities to create economies that help keep costs down. First production scheduling is for 10 machines, but P&W plans to step up production to 20, 40, and finally 100.

The company is showing its faith in the new numerical control by using it extensively on the Tape-O-Matic production line. Numerically-controlled tools will drill circuit cards and wire wrap terminal boards.

Another major cost saving stems from P&W's use of weldments instead of castings for the three biggest structural parts—the base, the column, and the detachable head. With this change from conventional design, P&W has swept away one of the most durable of the machine tool industry's phobias, the insistence on heavy castings for structural parts.

In the control, instructions on punched paper tape are fed to a Tally reader which dumps them into storage

registers whose capacity equals tool slide travel. An ac motor moves the tool slide at 300 in. per min for traversing and a pulse motor runs it at slower speeds (8 and 0.5 in. per min) for approaching. Feedback impulses from a coded disc transducer count down the register's contents.

The drilling head of the tool can be replaced by a turret head, grinding head, wire wrapping head, or gage head, to increase versatility.

Italy Parades Its New View of Automatic Control

Italian control engineers are following the same path U.S. engineers trod a couple of years ago. But it represents a major change in Italian thought. Traditional opposition to mechanization and automation is waning.

TURIN—

"This might have been an Instrument Society of America technical meeting three years ago," a U. S. visitor said, commenting on the presentations and discussion at the International Automation Congress held here in September. "European engineers have espoused solid state electronics; they are skeptical about closed-loop computer control of processes; and they are starting to get interested in numerical control of machine tools. It all sounds very familiar," he added.

Over 300 European engineers attended the Congress which had been organized by ANIPLA, the Associazione Nazionale Italiana per l'Automazione. The meeting, however, fell short of the group's ambitious aim of presenting much that was truly significant. Still it spotlighted a growing interest in automatic control in Italy and the surrounding countries.

One trend seemed clear. The future of automatic control in Europe is being identified closely with electronics, with reliable plug-in semiconductor modules that can be assembled readily in a variety of control devices.

• **Computers for control**—The concept that a computer can control a process is just beginning to take hold in Italy. Manufacturers have found Italian engineers expressing strong skepticism. The usual arguments against computer control: there is a need for precise sensing devices to measure process variables accurately,

and process engineers do not know enough about plant dynamics to derive the process equations necessary for computer control.

An indication that the skepticism is being breached was given by the chief mechanical engineer of Edisonvolta, Italy's largest supplier of electricity, who told the congress that the utility will install a computer at its new 655-megawatt plant at La Spezia. The machine, to be connected to about 1,000 analog inputs from two generating units, will perform alarm scanning, data logging, and calculate efficiencies for manual optimization. Installation is to be justified on the basis of improved plant safety. But, closed-loop control, automatic startup and shutdown are not being considered now.

If the European computer market appears to be ready to grow, competition is already growing rapidly. IBM, Remington Rand, Packard Bell, Olivetti Bull, and Thompson Ramo Wooldridge were all at the meeting eager to sell.

• **Snapshot**—One group of presentations was designed as a snapshot of the present state of the art of control in Italy. Many of papers were surveys of what's happening in Europe in the control business. Others reported some specific applications that have been installed and put on line:

▶ A method of synchronized speed control with saturable reactors to regulate large industrial ac motors. A complete system was said to be much less expensive than control with dc motors and magnetic amplifiers.

▶ Two closed loop controls for the cigarette industry were discussed. One, a gamma ray densitometer, was instrumental in controlling cigarette weight. The second incorporated a pneumatic gage to regulate the diameter of filter-tip cigarettes.

▶ An integrated steel plant used a medium-sized digital computer to control production as a function of incoming orders.

▶ Installation of direct dialing for the Italian telephone system.

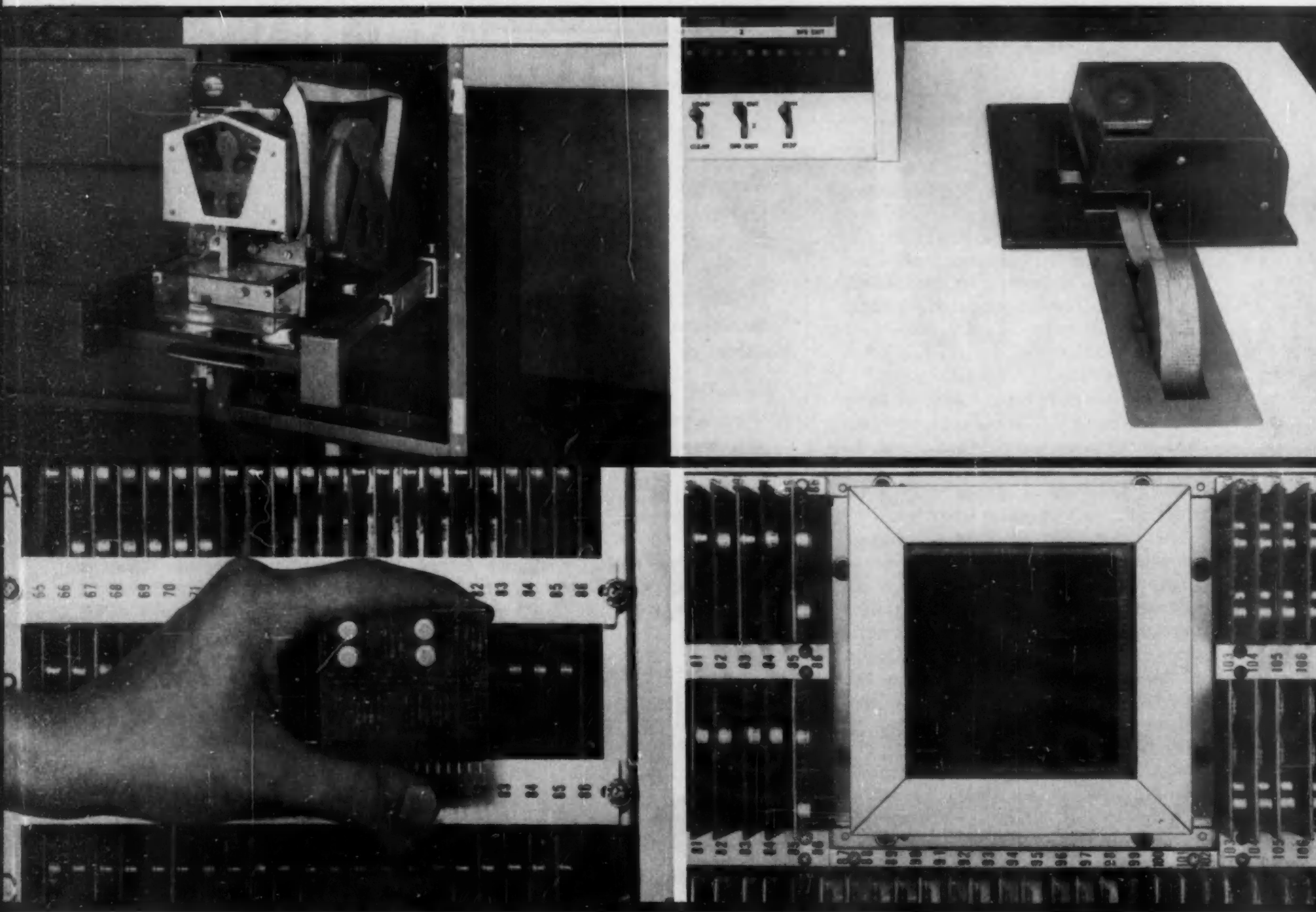
Although the congress was disappointing to some severe critics, to many other visitors it was a most encouraging event. Italy and the Italian worker have had a history of bitterly opposing automation and installation of automatic controls. Only in the last two years has there been a lessening of opposition. That this congress was held is taken as additional evidence that the walls of resistance are coming down.

—Gene DiRaimondo
McGraw-Hill World News

(Continued on page 40)

NEW CONTROL DATA

Technical Information Series #1
The 160-A Computer



Sellouts, Acquisitions, Licensing Pacts Spree Continues

Rheem Sells Semiconductor Firm to Raytheon

New phase of the expected shakeout in the semiconductor industry was reached in October when Rheem Manufacturing Co. sold its Rheem Semiconductor Corp. subsidiary to Raytheon Co. "Intensified competitive pricing conditions" were cited by Rheem president, A. Lightfoot Walker, in his announcement.

The turmoil in semiconductor device pricing (see CtE, Oct. '61, p. 148) was probably involved in CBS Electronics' selling out earlier in the fall—also to Raytheon. The agreement between Rheem and Raytheon, while not yet in final form, calls for the Lexington, Mass., firm to acquire substantially all the assets of the Rheem subsidiary, including a leased plant in Mountain View, Calif.

Rheem Semiconductor has specialized in advanced silicon devices. Raytheon will continue its operation and will add its distribution network to sell Rheem products.

Schlumberger Adds Control of Solartron to Skein

LONDON—Schlumberger Ltd. has made another move to become a major controls supplier by contracting to purchase the 56.7 percent interest in Solartron Electronic Group Ltd. held by Firth Cleveland Ltd. The $5.39 million deal is the second major acquisition move announced by the international oil field equipment company in three months; in September Schlumberger made plans to acquire Daystrom, Inc. (CtE, Oct. '61, p. 152).

Firth Cleveland, an industrial holding company, bought control of the British company in January 1960 for the equivalent of $8.40 a share. It offered to buy the remaining shares last August for the same price, but the bid was rejected as too low by the remaining Solartron shareholders.

The holding company was forced into the sale by a liquidity problem: it has a current overdraft of almost $4.76 million. Solartron has been eating up big sums for development costs; R&D expenditures left only $21,764 from 1960 pretax profits of $315,403.

Schlumberger will offer to buy the remaining Solartron holdings after a Solartron recapitalization.

RCA Set to Deliver Mammoth Computer Orders Overseas

As part of its recently announced licensing and information exchange agreement with Compagnie des Machines Bull (CtE, Sept. '61, p. 230), Radio Corp. of America has begun shipping to the Paris company the largest sale of commercial data processing equipment. On top of this, RCA has signed a similar agreement with International Computers and Tabulators Ltd. of England.

The Bull pact calls for the sale of a minimum of 50 and a maximum of 100 RCA computers. The ICT agreement, announced late in October, includes an initial order of 50 data processing systems, with an option for 50 or more additional systems. Quantity shipments under both agreements will begin about next July.

The RCA-ICT contract also calls for nonexclusive licenses for sale and manufacture. Technical information will also be interchanged.

News of Other Companies of the Control Field

Martin Co., Div. of Martin Marietta Corp., Baltimore, Md., has set up an Electronic Systems and Products Div. to handle all its efforts in this area. Charles D. Manhart has joined Martin from Daystrom, Inc., to be vice-president in charge of the new division. Electronics now represents over a third of Martin's total business.

Imm Industries, the No. Hollywood, Calif., company founded earlier this year by Louis Imm, former president of Librascope, has acquired Digital Servo Corp. and Lane Electronics Co., both of No. Hollywood. Lane deals in custom airborne electronic and ground support equipment and computer checkout devices. Digital Servo produces digital servomotors, servomechanisms, and other control gear. Imm has also invested in a new Sunnyvale, Calif., company, Signetics Corp., formed by four former Fairchild Semi-

(Continued on page 150)

Now only from RCA

World's First Silicon PLANAR EPITAXIAL Switching Transistor in the miniature TO-46 Package

2N1708 Shown Actual Size requires only 40% of TO-18 Headroom

RCA announces the 2N1708, first and fastest silicon planar-epitaxial computer transistor in the TO-46 package

PLANAR CONSTRUCTION for excellent stability, high reliability. Collector cut-off current reduced by a factor of 20 to 1 over mesa types. Uniform beta over a wide current range. Maximum storage temperature—300°C.

EPITAXIAL CONSTRUCTION for low saturation voltage and improved switching times.

MINIATURE CASE for extremely high density packaging. Uses same lead arrangement as TO-18 package but requires only 40% of the TO-18 headroom.

BROAD SILICON LINE The new 2N1708 planar-epitaxial transistor is another example of RCA's advanced silicon technology, application-oriented to today's performance and miniature packaging requirements. The 2N1708 complements the other RCA silicon planar switching transistor types: USA 2N706, 2N706, 2N706-A, 2N708, 2N696, and 2N697.

Check the data on these outstanding RCA types. For information on RCA computer transistors and multiple switching diodes, call your RCA Field Representative. All these types are immediately available in quantity. For further technical information, write to RCA Semiconductor and Materials Division, Commercial Engineering, Section K-56-NN, Somerville, N. J.

	RCA 2N1708	
CHARACTERISTICS	TEST CONDITIONS	LIMITS
I_{CBO}	V_{CB} = 15 volts; $I_E = 0$	.025 μa max.
I_{CEX}	V_{CE} = 10 volts; V_{BE} = 0.35 volts; Free-air Temp. = 100°C	15 μa max.
V_{CE} (sat.)	I_C = 10 ma; I_B = 1 ma	.22 volts max.
V_{BE} (sat.)	I_C = 10 ma; I_B = 1 ma	.9 volts max.
t_s	I_C = 10 ma; I_{B_1} = 10 ma I_{B_2} = 10 ma;	25 nano-seconds max.
$t_{\text{"on"}}$	I_C = 10 ma; I_{B_1} = 3 ma; I_{B_2} = 1 ma; V_{CC} = 3 volts	40 nano-seconds max.
$t_{\text{"off"}}$	I_C = 10 ma; I_{B_1} = 3 ma; I_{B_2} = 1 ma; V_{CC} = 3 volts	75 nano-seconds max.

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Available Through Your RCA Distributor

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The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA

CIRCLE 41 ON READER SERVICE CARD

New! Sylvania CT4251

First

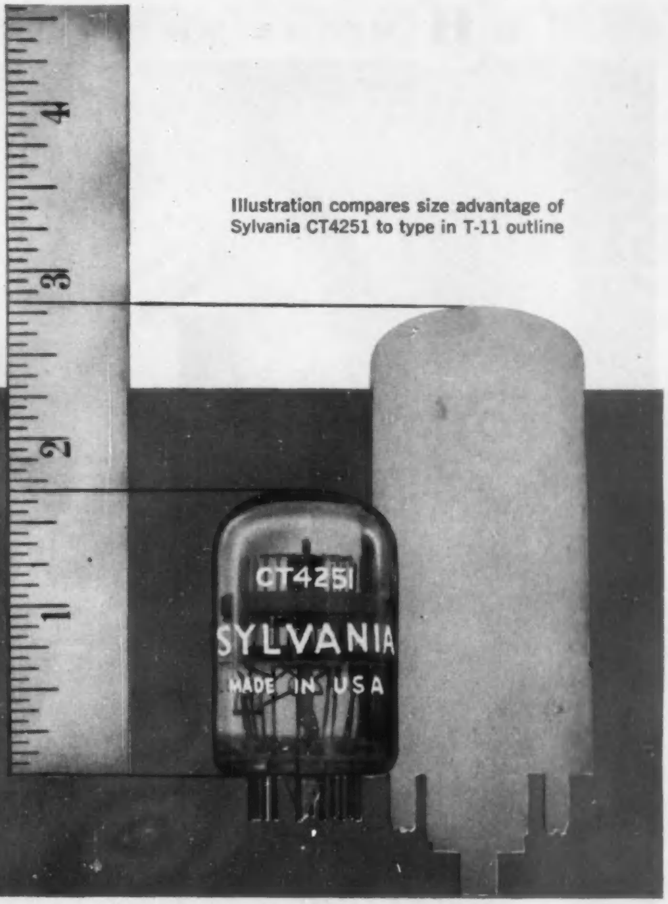
Compact

Decade Counter Tube

in Dome-Shaped T-9 Bulb

with 10 Output Cathodes

Illustration compares size advantage of Sylvania CT4251 to type in T-11 outline



Sylvania introduces the new CT4251 . . . opening a dramatic new approach to the design of very compact, low-cost counting equipment in the 0-50KC frequency range.

Utilizing a new dome-shaped T-9 bulb evacuated from the base, Sylvania CT4251 offers significant reductions in seated height. CT4251 features 10 output cathodes, offering the versatility and advantages of tube types previously available only in the T-11 bulb. Examples: electrical information can be fed from all 10 cathodes, enabling preselection of a count from 0-9; the diameter of the ring of cathodes is identical with that of types in the T-11 outline, providing excellent visibility of readout information.

Sylvania CT4251 is the lowest cost *cold cathode Decade Counter Tube* available. Combining electrical and visual readout functions, it offers extensive economies in circuitry and associated components. Sockets, too, for its 13-pin circle are as much as one-half the cost of sockets normally required for T-11 types. In addition, this new 13-pin circle makes it possible for Sylvania CT4251 to be designed into equipment using transistorized and printed circuit techniques.

Tests to date of Sylvania CT4251 indicate superior quality performance even under stand-by operation for 500 hours.

Your Sylvania Sales Engineer will be pleased to tell you more. Contact him or write Electronic Tubes Division, Sylvania Electric Products Inc., Dept.1312, 1100 Main St., Buffalo 9, N.Y.

Sylvania Type	Total Anode Current (mA)		Min. Anode Supply Voltage (Vdc)	Min. Double Pulse Amplitude (V)	Min. Double Pulse Width (μsec)
	Min.	Max.			
CT4251	0.65	0.8	400	–70	4

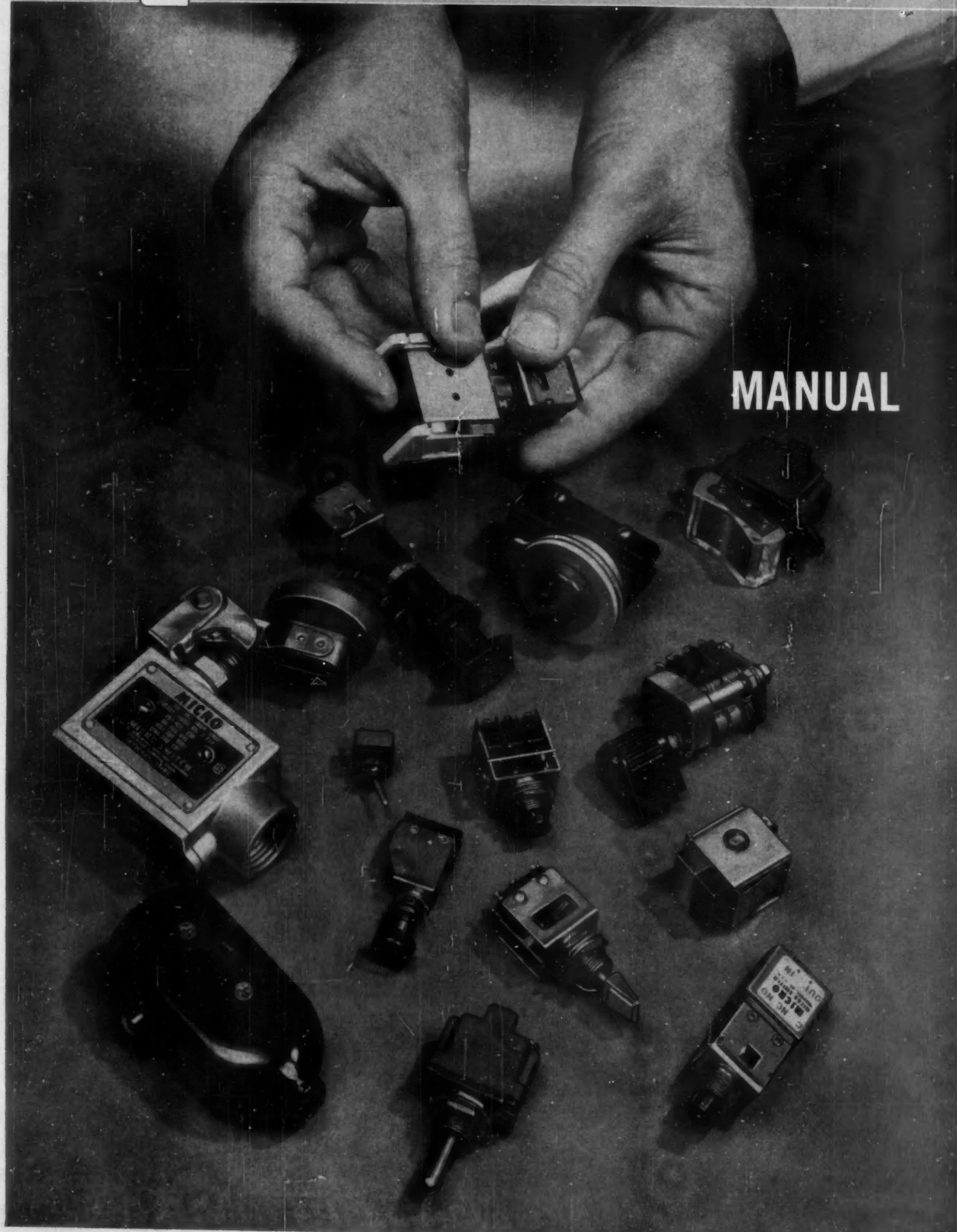
SYLVANIA

SUBSIDIARY OF

GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

CIRCLE 43 ON READER SERVICE CARD


MANUAL
MICRO

SWITCHES... DESIGNED TO MEET HUMAN-FACTORS ENGINEERING STANDARDS

Adjustable actuator arm. Oil-tight enclosure.

Heavy-duty palm button switch.

Explosion-proof switch with paddle type actuator.

Paddle actuator heavy duty splash-proof switch.

The application of Human-Factors to the engineering design of heavy machinery and electronic panels and consoles is receiving more and more attention today because efficient mechanical performance usually depends on efficient human operation.

In selecting manual switches, the factors include size, operating feel and force, mounting means, method of actuation—such as pushbutton, toggle, rotary or rocker. In the MICRO SWITCH line there are hundreds of switches in many variations to meet nearly every possible Human-Factors requirement.

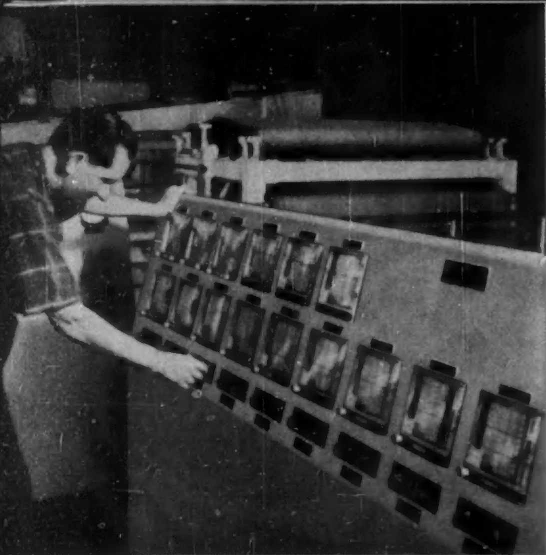
Available are varieties of circuitry, electrical capacities, terminals. For use under severe and hazardous environmental conditions, there are heavy-duty sealed and explosion-proof switches...and for customized panels, multi-circuit miniaturized pushbutton designs with miniature lamps under colored buttons.

No matter what your needs in switches, look to MICRO SWITCH. See the Yellow Pages for a nearby branch office or distributor. Or send for catalogs.

Left: An assortment representative of many families of finger and hand operated switches: Lighted pushbuttons, heavy duty designs, assemblies of pushbuttons and basic switch units, multiple circuit designs, and switches with a variety of electrical capacities and terminations.

MICRO SWITCH, FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls, Limited, Toronto 17, Ontario

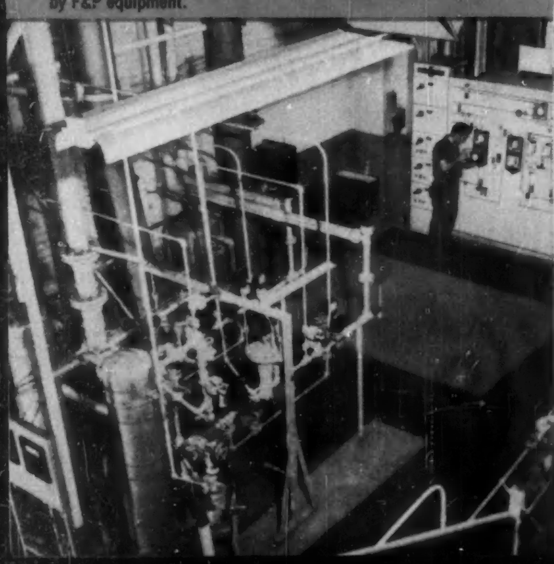
Honeywell
MICRO SWITCH Precision Switches



Master—and regulator—of all it surveys is the control console perched over the wet end of Marathon's #1 paperboard machine.

Battery of three F&P consistency regulators in the machine room at Marathon. These devices meter stock consistency and transmit control signals to recording control instruments.

Production of hypochlorite liquor is supervised from the graphic panel in the background. All variables metered and controlled by F&P equipment.



Marathon puts F&P control systems to work around the Rothschild Mill

Bleaching, paperboard production and water treating supervised by Fischer & Porter instrumentation

Marathon's first mill in Rothschild, Wisconsin has seen many technological advancements in papermaking during its half century of operation. Instrumentation has matched or even paced the perfection of many pulp, papermaking and chemical processes employed at this gigantic mill. In 1958, Marathon, a Division of American Can Company, employed Fischer & Porter instrumentation and know-how to regulate their continuous bleach plant. After this satisfactory service, F&P equipment was specified for other processes.

F&P Instruments Supervise Key Process Variables in Bleaching Operations

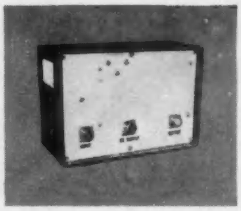
Separate graphic panels supervise the continuous bleach plant and the bleach liquor unit—the first of its kind using calcium. Measurement, transmission and control instrumentation for both processes are handled with F&P equipment. The efficiency of this instrumentation led recently to the specification of Fischer & Porter controls in other areas of the Marathon mill.

Paperboard Machine Control and Water Treating Instrumentation Point Up F&P's Diverse Capabilities

New instrumentation for the wet end of the No. 1 paperboard machine was completed in late 1960. Flow and consistency of stock, levels in various chests—all are measured and controlled by F&P equipment. In the basement, under the big 7-cylinder machine, are obstructionless magnetic flowmeters, indicating transmitters, pneumatically operated Ratogate stock valves, and dp transmitters.

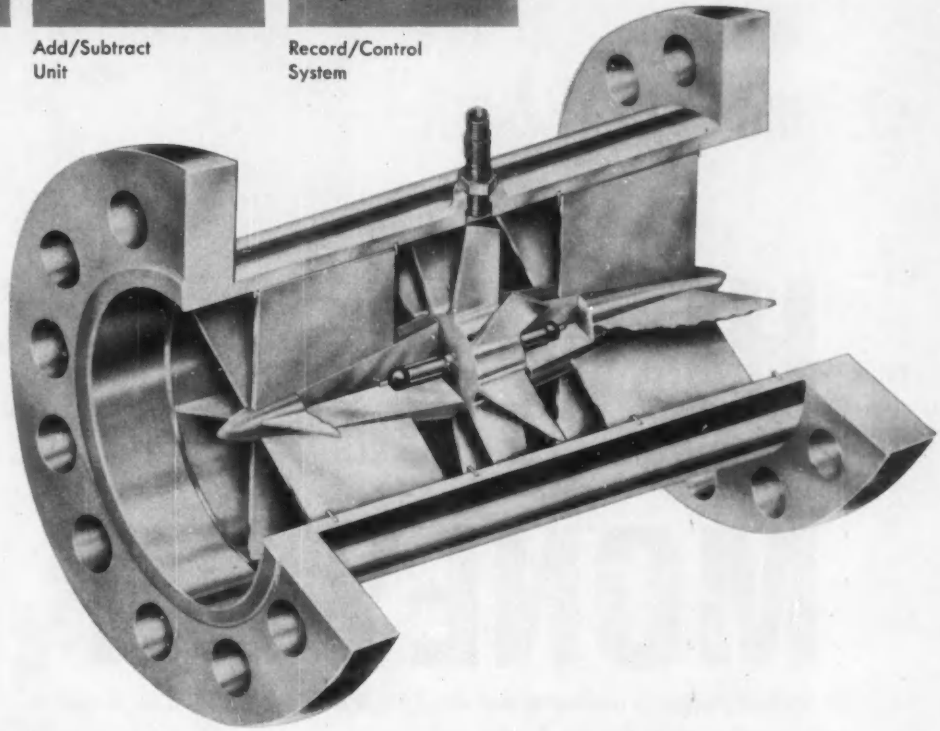
At the other end of the mill, over five million gallons per day of river water get careful treatment for use in the pulp, paper, and by-products operation. F&P instruments take care of this operation, too—metering and controlling chlorine dosage, silica feed, pH, flow and pressure.

Totalizer/
Transmitter



Add/Subtract
Unit

Record/Control
System



CORROSIVE AND ABRASIVE FLUID FLOW ACCURATELY CONTROLLED

...even with reversals in flow direction

The Halliburton Turbine Flow Meter is a rugged, in-line instrument designed to electronically measure the flow of corrosive and abrasive fluids. It is designed for minimum maintenance and *no lubrication*. Companion readout equipment available for the Flow Meter includes:

ADD/SUBTRACT UNIT which utilizes the Flow Meter's unique ability to accurately measure fluid flow in either direction. This unit transforms flow data transmitted from the Flow Meter into a constant inventory reading of *any* storage system while it is being filled or drawn upon.

The new Halliburton Flow Meter Brochure tells the full story of these two new instruments plus the Flow Analyzer, Rate Meter, Totalizer/Transmitter, Batch Indicator, and Record/Control System. Write for a copy today to . . .

SPECIAL PRODUCTS DIVISION

Halliburton

COMPANY . DUNCAN, OKLAHOMA

New ideas...
reliable products...
seasoned experience...

Sanborn® 7-Channel FM tape system for $6800* complete

uses interchangeable FM and direct record/reproduce electronics entirely contained in 7″ x 19″ panel space

COMPARE PERFORMANCE, PRICE PER CHANNEL

Here is the ideal combination of high performance *and economy* in a 7-channel, 4-speed system that meets IRIG Telemetry Standards. *Versatility* is another advantage. The Model 2000 system uses interchangeable Sanborn FM or direct record/reproduce electronics — all solid-state, in 7″ of panel space — and you can have any combination of direct and FM channels simply by changing circuit cards. Recording capability may be extended beyond the system's minimum input levels through the use of Sanborn "850" and other compatible amplifiers.

The Model 2000 Magnetic Data Recorder has four speeds and uses standard ½-inch tape on 10½-inch reels. All controls are on the front, and several convenience features are included: an integral FM Alignment Meter that eliminates the need for electronic counters, an automatic squelch, a tape footage counter, and provision for using one channel for flutter compensation.

Complete details are available from Sanborn Sales-Engineering Representatives in principal cities throughout the U. S., Canada and foreign countries.

**Price FOB Waltham, Mass., in Continental U. S. A.; subject to change without notice. State and local taxes must be added where applicable.*

(Specifications subject to change without notice)

SPECIFICATIONS

Input ± 2.5 V into 10,000 ohms, single ended, adjustable.

Output ± 2.5 V into 1,000 ohms or more, single ended; level, position adjustable.

Bandwidths (Max)

Speed	*FM*	*Direct*
3¾″/sec	0-625 cps	50-6,250 cps
7½″/sec	0-1,250 cps	50-12,500 cps
15″/sec	0-2,500 cps	50-25,000 cps
30″/sec	0-5,000 cps	100-50,000 cps

(100% modulation on FM = ± 40% carrier deviation)

Linearity Maximum error due to nonlinearity: 0.2%.

Drift ± 0.5% of full scale for 10 V power line change, 10°C ambient temperature change, or for 24 hours at constant power line voltage and ambient temperature.

Signal-to-Noise Ratio (Min)

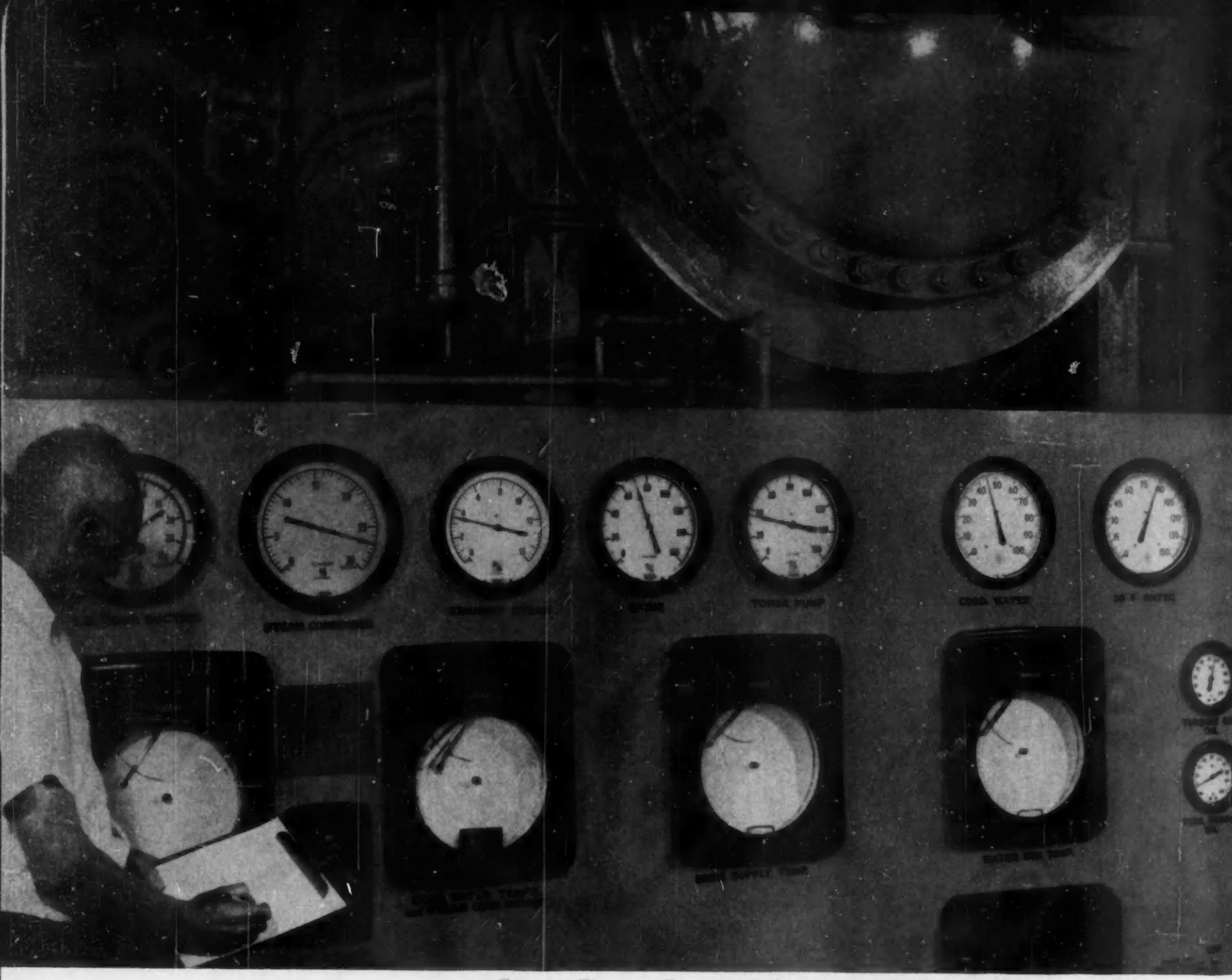
Direct: 40 db at all speeds.

FM: 40 db RMS at 30″/sec and 15″/sec; 35 db RMS at 7½″/sec; 33 db RMS at 3¾″/sec.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Massachusetts

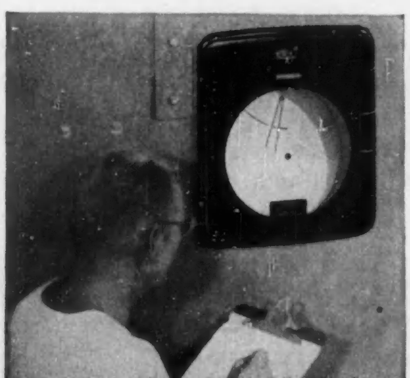
Readout, as well as input monitoring during magnetic recording, may be provided by this compatible 17-inch, 8-channel Viso-Scope or other Sanborn monitoring instruments, or by direct writing systems.

CIRCLE 51 ON READER SERVICE CARD



Foxboro Dynalog Electronic Controllers in Utilities Division, at Kodak Park, Rochester, N. Y. control distribution of refrigerated water throughout Kodak Park Works.

motor load – conductivity – pH – capacitance . . . Eastman Kodak uses Foxboro Electronic Dynalogs for dependable measurement and control



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One basic instrument measuring and controlling these and dozens of other different variables: temperature, weight, moisture, conductivity, pAg, flow, humidity. That's what Foxboro Dynalog* Electronic Instruments do at Kodak Park Works in Rochester, N. Y.

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Here's real measurement versatility—a null meter, a dc voltmeter and a high-gain amplifier—all in one compact instrument!

To provide for high sensitivity, high input impedance, low noise and drift, high ac rejection, *plus* superlative resolution and stability, the new hp 413A employs the hp-pioneered photoconductor chopper and other precise circuitry of the popular hp 412A Voltmeter-Ohmmeter-Ammeter.

As a dc voltmeter, hp 413A offers high input impedance and input isolation from ground that allows operation up to 500 volts dc or 130 volts ac from ground potential. It measures from 1 mv to 1,000 volts end scale in 13 zero-center voltage ranges, providing 2% accuracy and virtually drift-free operation. The 413 is especially useful in resistance bridge measurement.

As an amplifier, the hp 413A provides an output proportional to meter deflection, offering gain from 0.001 to 1,000 in 13 steps. Extreme linearity, high stability and low noise make it ideal as an indicating and control device. Typical application is for amplifying the output of a thermocouple in control systems, the zero set establishing an arbitrary reference.

Moderate price plus Hewlett-Packard superior engineering and manufacturing standards, make the hp 413A today's best value for flexible null and voltage measurement, and amplification requirements.

Specifications

VOLTMETER

Ranges: Positive and negative voltages, 1 mv to 1,000 v end scale, 13 zero-center ranges.

Accuracy: ±2% of end scale value

Input Impedance: 10 megohms on 1, 3 and 10 mv ranges
30 megohms on 30 mv range
100 megohms on 100 mv range
200 megohms on 300 mv range and above

AC Rejection: A voltage at power line or twice power line frequency 40 db greater than full scale affects reading less than 1%. Peak voltage must not exceed 1,500 v.

AMPLIFIER

Voltage Gain: 0.001 to 1,000 in 13 steps

Gain Accuracy: ±1½%

Gain Linearity: ±0.2%

Noise: Less than 0.1% (rms) of end scale on any range

Output: 1 volt for end scale deflection, same polarity as input. End scale corresponds to 1.0 on upper scale. Max. load current, 1 ma.

AC Rejection: Approx. 3 db at 1 cps, 80 db at 50, 60 cps

Input Isolation: Greater than 100 megohms shunted by 0.1 μf to instrument case (power line ground)

Common Signal Rejection: May be operated up to 500 v dc, or 130 v ac above ground

Dimensions: 11½" high, 7½" wide, 10" deep (cabinet); 5¼" high, 19" wide, 7½" deep behind panel (rack mount)

Price: hp 413A, $350.00 (cabinet); hp 413AR, $355.00 (rack mount)

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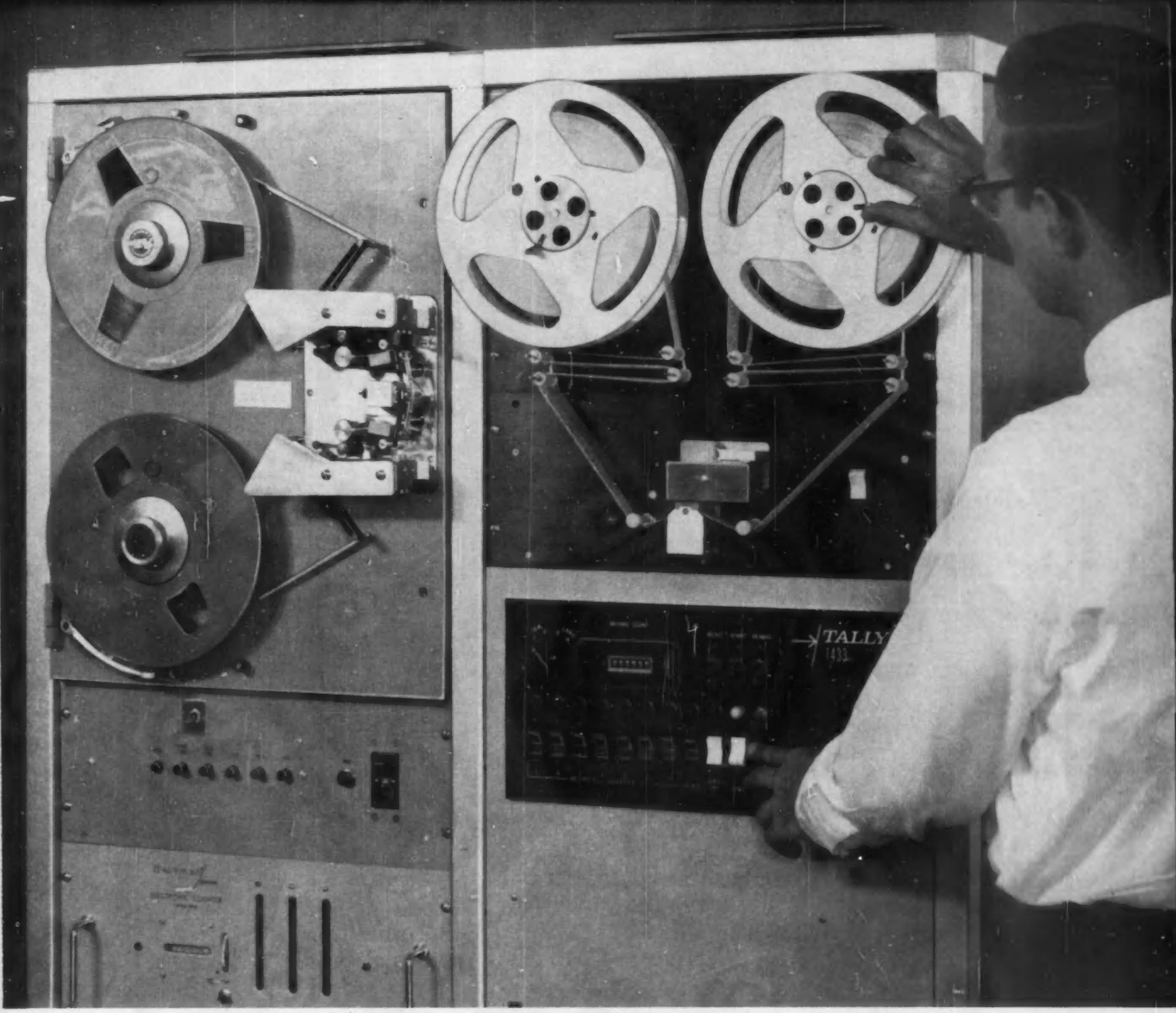

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Tally's new solid state Model 1433 Paper-to-Magnetic Tape Converter is not 10 years ahead of its time. You can solve today's media conversion problems with both integrity and economy.

Normally, input and output data are completely identical in content. The output record is a bit for bit image of input data. A universal code conversion feature is, however, available.

Without changes or adjustments, the Tally converter will accept paper, foil, or plastic tapes in widths varying from 5 through 8 levels. It writes data on magnetic tape compatible with IBM 727, 729 Mod 1, and Remington Rand computer formats. Other formats are also available.

Complete in itself, the system includes a 120 cps paper tape reader, a Potter magnetic tape handler, and necessary electronics. Price of the Model 1433 begins at $26,500. Delivery is currently 120 days. More information can be obtained from your Tally engineering representative or by writing

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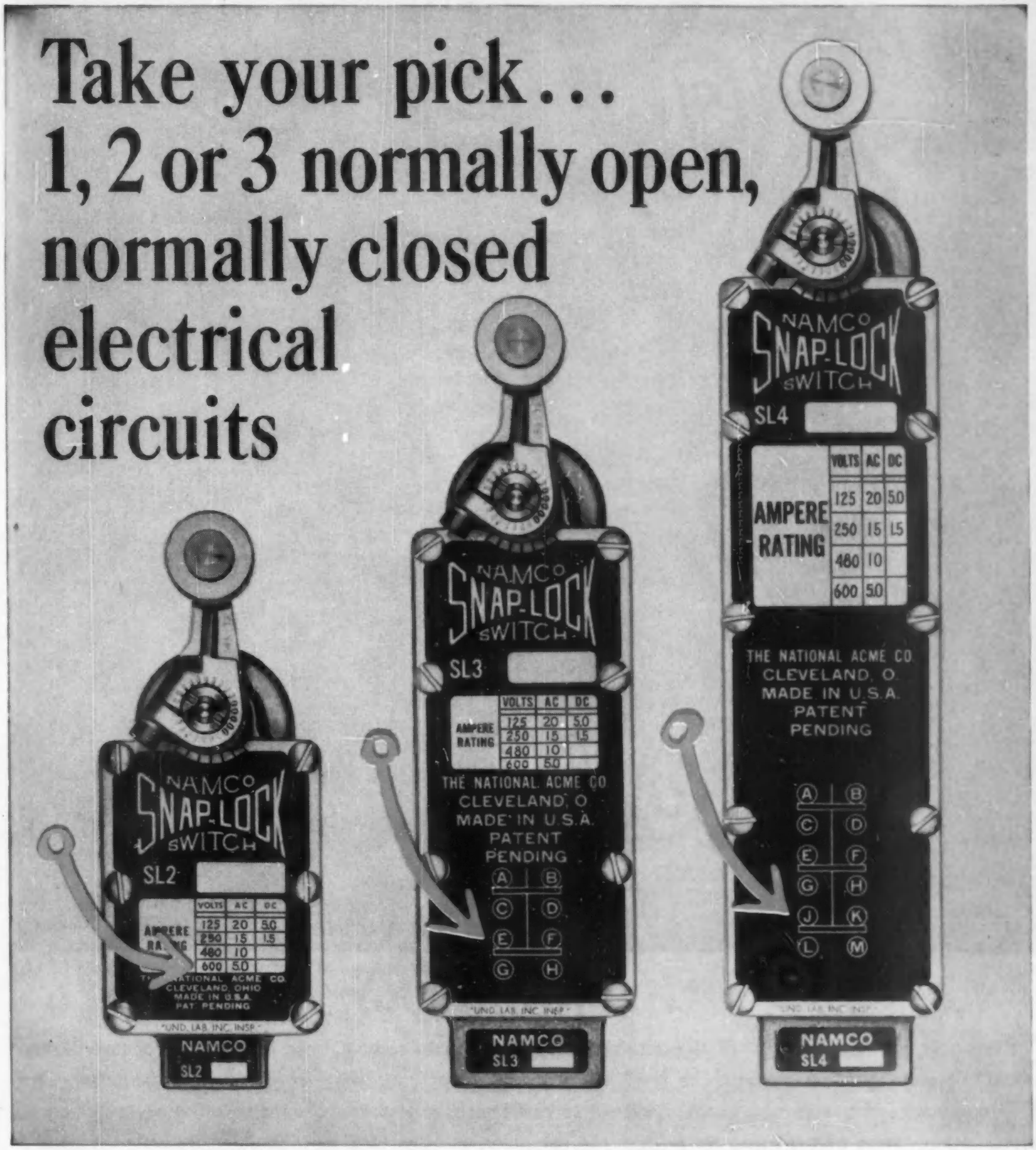

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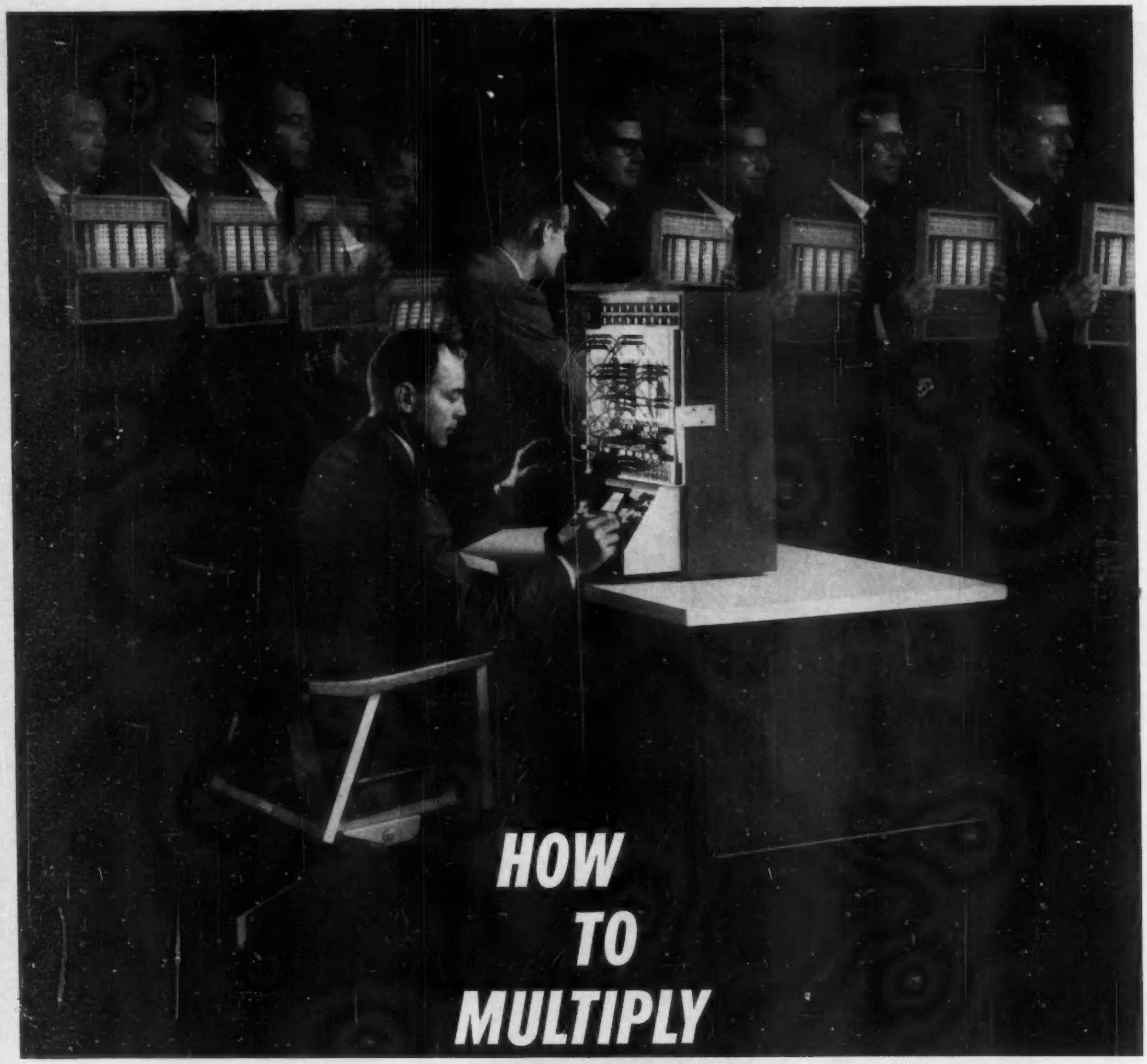

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Controls Market Booms with Space Technology

Appropriations for space technology are likely to add up to $3 billion in fiscal 1962, the government's accounting year that started July 1. The share of such monies going for instrumentation and control equipment, already large, seems sure to increase. In 1959, electronics, instrumentation, and control accounted for about 35 percent of the money spent on missiles. This same kind of gear is expected to take 50 percent of the 1965 expenditures for missiles and space technology and 65 percent of all dollars spent in 1970 for missiles and space technology.

Awesome sums

Businessmen are frequently awed by the kind of money involved in a typical space project and rightly so. For example, figurers at the National Aeronautics and Space Agency think it will cost over $20 billion to put a man on the moon. Probably half of that will be spent for instrumentation and control equipment.

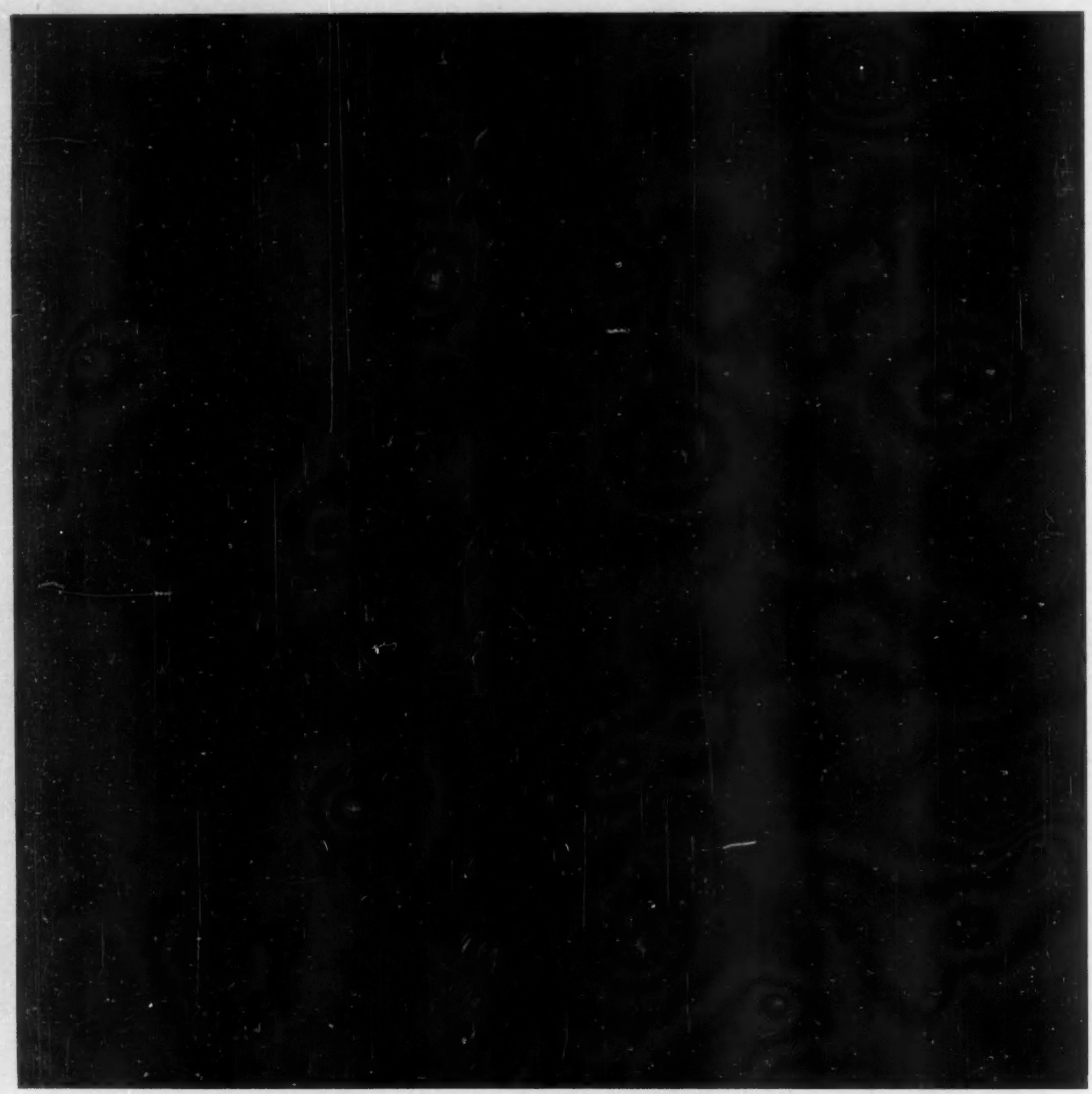
It is difficult to break out NASA or Defense Department expenditures for instrumentation and control because neither agency budgets that way. And there are a lot of broad development groups that are hard to incorporate into such a listing. For example, NASA advanced study groups are spending several million dollars developing solid state detectors but there is no easy way to total the expenditures.

Typical spending

Probably the best way to see the market for control in space technology is to examine totals for some specific projects and then apply some rules of thumb that NASA administrators have evolved. Here are some important typical projects with the spending estimated for fiscal 1961 and 1962:

Project	Spending (Millions of Dollars) Fiscal 1961	Fiscal 1962
Scientific satellites	$172.9	$288.5
Saturn	118.1	224.2
Apollo	1.0	160.0
Lunar probes	71.5	159.9
Communication satellites	21.9	94.6
Mercury	109.5	74.2
Centaur	62.6	56.4
Meteorological satellites	18.1	50.2

With scientific satellites and meteorological satellites, for instance, you can figure that 50 percent of the total cost will buy instrumentation, control and test equipment. The remaining 50 percent goes for ground construction for launching and rocket power plant to launch the vehicle. At NASA, J. L. Mitchell, chief flight systems, scientific satellites, divides satellite spending for the 50 percent of interest to control engineering this way:



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Breakdown

Sensors for the experiment and other instrumentation	25 percent
Stability and control equipment	20
Data handling and communication equipment (includes computers)	20
Ground support equipment	10
Environmental test equipment	10
Structure	10
Power supplies (solar cells, batteries, thermo-electric units)	5
	100 percent

And this breakdown also applies approximately to meteorological satellites, lunar probes and other space projects with exploratory and experimental objectives.

What helps run up the cost of scientific satellites is the present need for at least three of everything. Every project has a complete prototype space craft, (the payload), a refined model for the launch into space, and an identical copy for backup. In addition, most projects order extra spare parts of important instrumentation and control. The Orbiting Astronomical Observatory, for example, will cost almost $30 million to deliver the first two space craft.

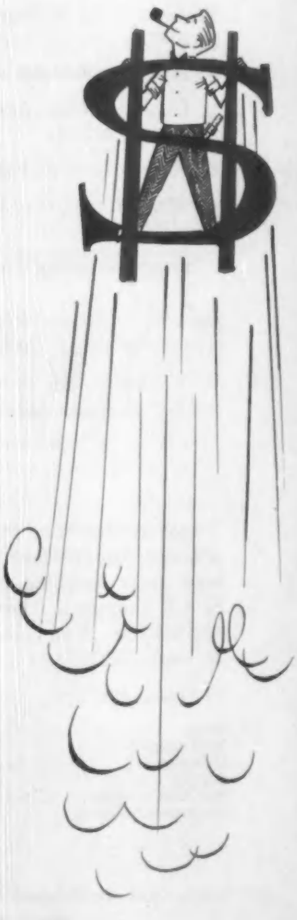
Technical Events

The expenditure of such tremendous sums is certain to speed up the technology and a number of trends are already developing. One is the design of solid state detectors, tiny reliable devices to measure radiation across the whole electromagnetic spectrum. Another is the increased study of the ultraviolet spectrum. New interest in the sun, both purely scientific and as a target for guidance and stabilization control, is spurring research into basic UV phenomenon, new techniques for measuring it, and new instrumentation hardware.

In communications, the trend is toward more complicated command control systems. In the first scientific satellites, commands from the ground were generally limited to turning something on or off. Now NASA is applying an audio tone system that can transmit up to 10 different commands for many devices. On the development schedule, however, are digital coded command systems capable of transmitting over a hundred different commands.

In those projects involving men in space, like Mercury and Apollo, you find space administrators staying away from the radical new advances in technology. The chief requirement is reliability so NASA won't put anything into such a project unless the product has been tried and proven.

That means that not all space control work is exotic and on the frontiers. While space planners eye advances like molecular electronic computers (see page 22) with interest, many of them would rather have a good seal to protect delicate devices against the ravages of the vacuum of space or mechanisms that move easily without bearings.



Scientific satellite chief flight engineer Mitchell, for example, doesn't dream of a solid state inertial guidance system or an adaptive control system with heuristic programming. What Mitchell needs most right now is a small magnetic tape recorder that will work day after day for years, 100 percent of the time. Even the billions spent on space so far haven't helped develop a product with that kind of reliability.

Control ENGINEERING

DECEMBER 1961

Pro or Plumber

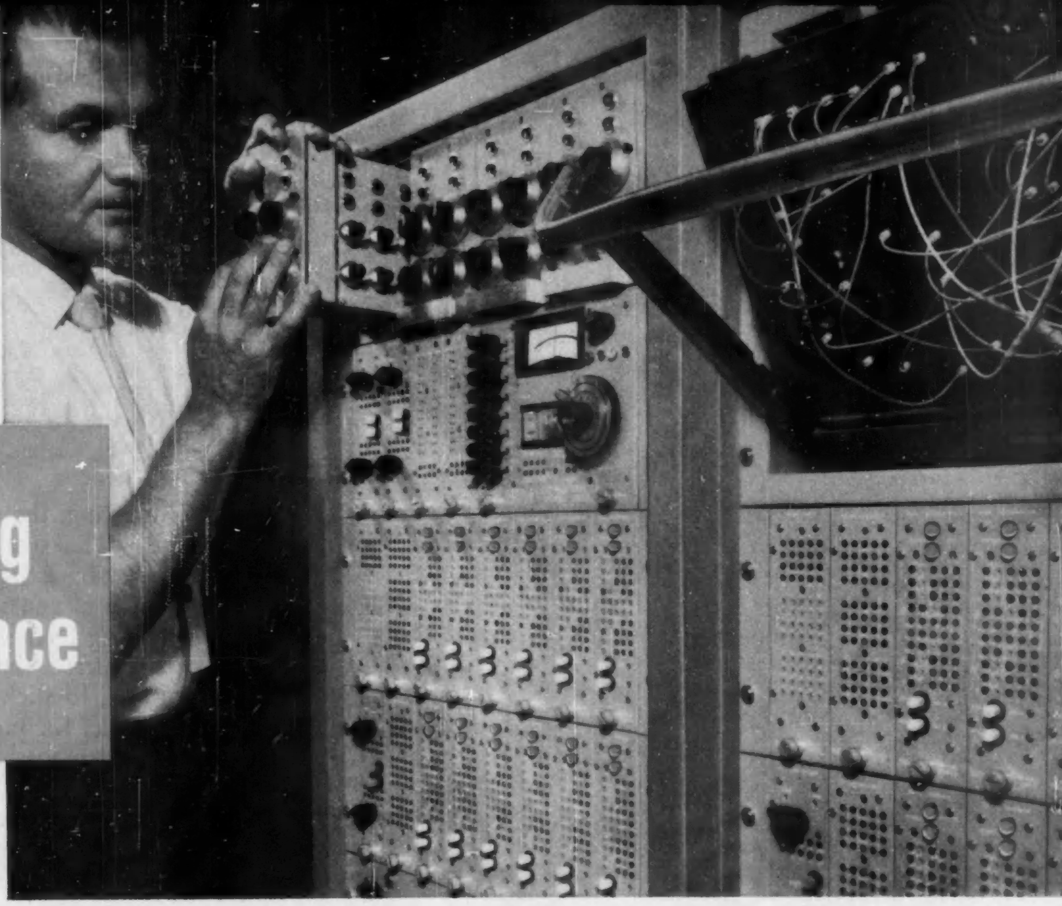
A short while ago at an industry control meeting, the conferees were obviously divided into two opposing camps. The smaller group—the professionals—was interested in finding out more about the processes they were dealing with, in taking maximum advantage of newly available control techniques and equipment, and in calculating to the last penny the economic return of automatic systems. In contrast, the majority—the "plumbers"—wanted to maintain the status quo, to stick to the simple control loops they'd been using for years, and to let the process designers and operators worry about economic return and process idiosyncrasies. Fortunately the percentage of control professionals is on the rise, while the plumbers are being forced to beat a slow but steady retreat.

It's a lot harder to be a professional than a plumber. You've got to be willing to push the use of control and to gamble, rather than sit back and let someone else bring the jobs to you. At the very minimum you'll be working with Bode diagrams, phase-plane plots, or Boolean algebra, and you may well get involved in regression analyses, dynamic programming, or noninteracting controllers. New applications will create unusual problems: which antenna drive will handle a dynamic range from Earth rate to high speed slewing? How about a valve and actuator for 40,000-psi control service? Where do you find a linear position transducer accurate to 3 microin? Your professional life will consist of study, reading, advanced analysis and design, and testing, while the plumber rests in an existence of comfortable familiarity.

Faithfully reading Control Engineering is probably hard work for many of you. Even though our engineering editors spend hours trying to interpret ideas and improve readability, it is only possible to simplify so much. Further watering down would yield superficial material, of casual interest to the plumber but of no real use to the pro. Properly applying the latest products and techniques is a complex job, and there is no substitute for education and experience.

Where's the payoff?, you might say. It's in being able to produce a product automatically that your competitor can't make at all, in developing a more accurate guidance system for a missile, and in turning out better steel more cheaply than a foreign producer. Pure economics is forcing the plumbers out and the pros in.

Byron K. Ledgerwood



Analog Advance

The all new 60 amplifier .01% Donner 3200 is the first computer designed from the ground up to use the new iterative technique

Every important assembly in the completely new Donner 3200 series iterative computer combines better performance and more features in less space than ever available before from any maker at any price.

The user can start with as few as 10 amplifiers and expand to 60 as necessary. Two or more 60 amplifier computers can be slaved to solve more complex problems. This flexibility is the product of a new packaging concept which emphasizes modularity and etched wiring. The plethora of cables usually associated with computers is gone but hardly grieved. Note these other unique features and specifications.

- **NEW AMPLIFIER** Bandwidth, 1 mc; drift, 20 microvolts per day; gain, 10^8; noise, 500 microvolts; output, ± 100 volts @ 20 milliamps. Three types of dual amplifiers are available—integrators, summers and inverters.

- **NEW DUAL MULTIPLIER** Solid state .05% quarter-square multiplier which can be programmed to function as multiplier, divider, or 2 squaring networks.

- **NEW FUNCTION GENERATOR WITH STORABLE PROGRAMS** Each module contains 2 independent 12-segment silicon diode function generators. Channels can be paralleled to provide 24 line segments. Programs can be stored by simply unplugging and removing the inexpensive potentiometer element from the function generator.

- **NEW POTENTIOMETER MODULE** Each compact module contains 20 fused precision potentiometers mounted on the smoothest drawer slides we've ever found. Eighty potentiometers take only 7" of panel height.

- **NEW CONTROL CENTER** Pushbuttons select these modes of operation: compute, hold, reset, automatic recycle, slave, audible overload indication, and automatic hold. A new reference potentiometer allows null voltage measurements accurate to 0.02%. Meter sensitivities which can be pushbutton chosen are 300, 100, 30, 10, 3 volts, zero centered.

Forward and reverse relay logic is incorporated for either iterative or continuous operation.

OTHER FEATURES The novel amplifier construction incorporates a built-in jack field on every module which helps the user get a quality computer for minimum cost and later, when he adds the standard removable patch board, he can use the amplifier patching bay as a built-in simulation board. Several sizes of removable patch boards are available both shielded and unshielded. All critical computing components are mounted in a temperature controlled environment.

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CIRCLE 66 ON READER SERVICE CARD

Separating Signal from Noise for Medical Diagnosis

THE GIST: Applying methods of separating noise from signal (as used in a military weapon system) to medical diagnosis (electroencephalography) was prompted by an article in Control Engineering (March '60, p. 147). This interdisciplinary idea-swapping took place over about a year's time, via correspondence.

WILLIAM L. STILL, U.S. Air Force, Gardena, Calif.

from
M. G. Saunders, M.D.
Electroencephalographer

(1) I have read your article with great interest . . . I think that some of the procedures you discuss may be applicable to collection signals in electroencephalograph records in a more adequate manner than present procedures. (3) . . . You ask: how does pulling a signal out of noise refer to electroencephalography? Any stimulus that comes through nerves from the skin, eye, or ear ultimately reaches the cortex of the brain, but by that time is of such low amplitude that it is virtually impossible to detect, due to background of normal EEG activity . . . which can be regarded as noise of a semi-predictable nature . . . If we could pull out these signals . . . we could test for the presence or absence of sensation in an unconscious or even anesthetized patient instead of relying on observations made by a conscious patient. (5) . . . In this particular strip there are about

from
W. L. Still, Major,
U. S. Air Force

(2) My knowledge of electroencephalography is not such that I can intuitively see any direct application of my work in this area . . . I should be interested in learning more, as there are many ways of detecting signals . . . They all revert to the determination of standards to define the many class characteristics of both signal and noise, and the development of techniques to test data against these standards. I have often seen clean signals extracted from a noise background so bad that you would never have guessed that a signal existed therein. (4) Let me restate your problem . . . you have a message (the external stimulus) which is transmitted through a communications medium (the nerves). After a finite but predictable delay the message arrives at the receiver (cortex of the brain). The problem is to test

17 flashes in 10 sec . . . the bottom channel is from a photocell recording light flashes from the GT 220 strobe light flashed into the patient's eyes. This flash activates the retina, sends a burst of activity down the optic nerves into the brain and this goes, among other places, to the back portions of the brain in the occipital area . . . you will notice a slight difference in the traces because this patient has had an interference with the blood going to the left side of the head . . . the difference in patterns is visible, but it would be helpful to show some quantitative difference in response to the flash of light. The averaged response (made by putting the strip on my EEG digital converter and feeding the data into our LGP 30 computer) does show this, but not as adequately as I would like, and due to averaging only 15 responses, I am not sure that the patterns are statistically significant.

for the arrival of this weak message in the presence of strong locally generated noise. I have no data on the characteristics of either the signal or the noise, but shall assume: (1) Both signal and noise consist of a series of random bursts of transmitted nerve impulses. (2) While the signal bursts arrive with random time delays, the envelope of the arrival will form identifiable probability distribution. (3) The noise is a pulsating signal with a reasonably predictable period. (4) The individual energy bursts for signal and noise are indistinguishable, i.e., signal and noise differ only in the energy grouping of the bursts, not in the bursts themselves.

Could you send me some actual traces of the type of signal and the noise environment, along with a few comments on the validity of these assumptions?

Signals in the Brain

An electroencephalographer's task can be complex and difficult—he diagnoses malfunctions and ailments of a complex organ, the brain, by analyzing electrical activity. At the moment this is done by visually scanning a record taken from eight areas of the brain simultaneously and which may be up to 150 feet in length. Patterns appear in this recording which represent spontaneous rhythmic activity from the brain. From experience, normal brains are associated with certain types of spontaneous pattern, abnormal brains with other types. Evidence is mounting to suggest that a better method of testing for malfunction of the brain is to input some sensory signal to it and detect its electrical response or signal. The spontaneous patterns, usually of far greater amplitude than the signal desired to be detected, would be now regarded as noise.

Electroencephalographic signals

In practice, a patient is exposed to a stimulus, such as from a flashing light. The stimuli are picked up by the patient's sensing organs and transferred by the nervous system to specific areas of the brain. The signal, an impulse mixed with noise, passes through a filter with a relatively fixed but unknown transfer function, as shown in block diagram form in Figure 1. Before the output signal can be read as on EEG trace, it is further corrupted by a mixture of both random and periodic noises at a high level. The EEG traces shown contain significant information. This patient was known to suffer a restriction in the blood supply to the left side of the brain. A strobe light, flashed at regular intervals, (shown at A), evoked a response that was read at both sides of the brain, and it is evident from the traces that there is a difference in response. However, when confronted with such traces, mixed with a large amount of noise, it is difficult for the electroencephalographer to state quantitatively just what the difference in response is.

The raw EEG trace, B, contains a signal component, a random noise component, and a periodic noise component. Some noise can be removed to obtain a clearer trace of the signal component, as shown at C, D, and E in Figure 1. To remove the periodic component, the trace was copied, shifted 180 deg, and then the original and copied signal were graphically added, forming C. To remove at least some of the random noise, about 15 signal cycles were digitized and averaged in a computer to produce the waveshape shown at D. Further smoothing techniques produce an even cleaner signal, as shown at E. With much of the noise removed, differences in response are more evident and it becomes possible to state that the blood-deprived (left) side of the brain responds to a stimulus faster, but more weakly than the normal side of the brain. This indicates also a means of extracting the meaningful portion of the signal from the noise.

Similarities between physiological systems and control systems are sufficiently strong that knowledge about one system can often be applied to the other

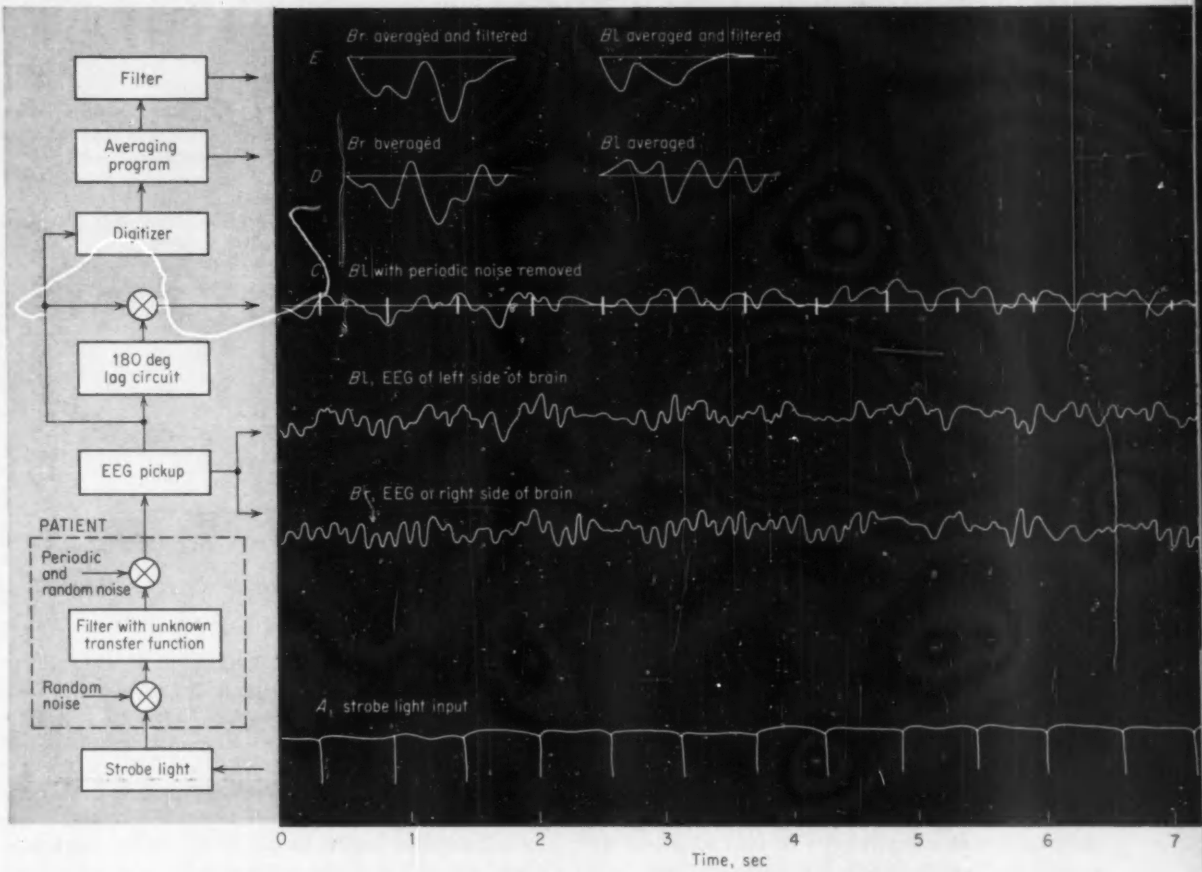
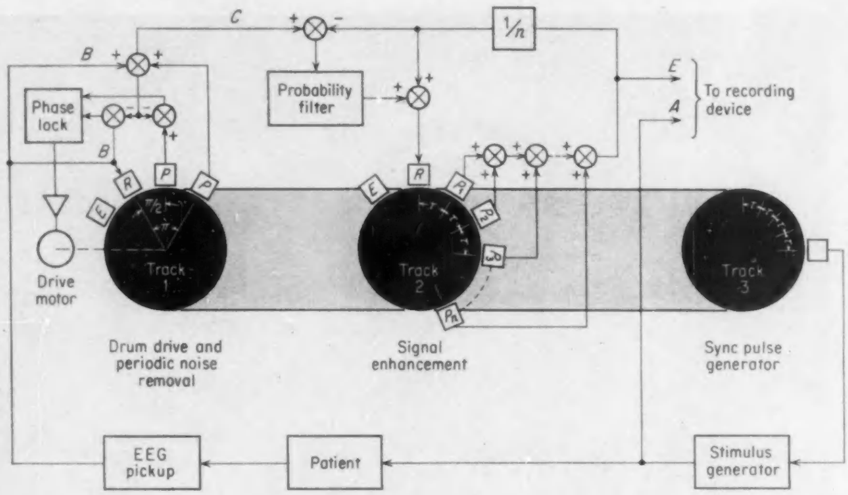


FIG. 1. Block diagram (left) of electroencephalographic system, and (right), the signals obtained directly as an EEG trace (Br and B1), and after filtering and noise removal (C, D, and E).

system, and this provides a basis for designing a system to obtain relatively noise-free signals. In communications terms, the objective is to establish the impulse response of a filter. Since there is no desire to pass information through the channel containing the filter, and insofar as the filter can be considered linear, the powerful tools of communications theory apply. To separate the signal from noise, a combination of four techniques offers the best means: 1) noise cancellation, to enhance signal to noise ratios; 2) probability filter, to establish the statistical significance of a relatively small sample population; 3) tapped delay line filter, matched to give maximum cross-correlation between the known input and the output; and 4) feedback from the output, to minimize the cross correlation between the desired signal component and the periodic portion of the noise.

Noise separation technique

These four techniques are combined in the system shown in Figure 2, which uses a magnetic drum to record and manipulate the raw signal between the EEG pickup and the EEG stylus. The first track receives the raw signal *B*, which is recorded with the drum running at some nominal speed. A pickup head is located a fixed distance from the recording head. By modulating the pickup signal against the incoming signal, standard phase locking techniques permit generation of an error signal. The error signal serves to vary drum speed until the two signals are in phase quadrature. This relates the basic noise frequency to the angle between the recording head and the pickup. A second pickup, placed twice the distance from the recording head as the first pickup, reads the signal 180 deg out of phase with the incoming signal. These two signals are added to cancel the periodic noise component, obtaining a signal resembling C in Figure 1, that contains only the desired signal and random noise. Since these will contain components which will show up as phase instability in the motor servo, they are sub-



E Erase head
R Record head
P Pickup head
n = number of pickups used
π = phase angle of periodic noise
$\tau = (2m + 1)\pi/2$,
m = any integer $\geqq 10$

FIG. 2. Closed-loop signal improvement system for extracting usable EEG signals from both random and periodic noise. The signals at points labeled A, B, C, and E closely resemble the patterns shown in Figure 1.

tracted from the inputs to the phase lock servo.

Between Track 1 and Track 2 the final signal output of the system is subtracted from the output of the periodic noise cancellation circuit. This leaves only the random noise, plus a quasi-random component of true signal left by residual noise in the final output signal. At this point, the signal-to-noise ratio is at a minimum. It now passes through a probability filter to insure that large noise bursts do not destroy the statistical significance of the final output. Output of the probability filter is then re-added to the system's final signal output.

At Track 2, a recording head writes this signal on the drum and n pickup heads read the signal. The pickups are separated by a relatively large angle to allow the expected signal to build up and die down during the transit time of a point on the drum from one pickup to the next. Judging from the EEG traces shown in Figure 1, the spacing should be about 10 or 12 cycles of the periodic noise. Signal strength adds linearly with the number of pickups, n, and the noise increases as the square root of n. Thus, the signal-to-noise ratio increases as the square root of the number of pickups used. Within the limits imposed by the frequency stability of the periodic portion of the noise, the amount of signal enhancement desired can be obtained simply by increasing the number of pickups. The summed output of these pickups forms the desired output signal to drive the EEG stylus. Part of the output signal is attenuated by $1/n$, fed back, and subtracted from the input to the probability filter to complete the noise cancellation cycle.

Track 3 is marked with permanently recorded impulses, spaced exactly the same distance apart as the pickups of Track 2, and used to trigger the stimulus inputs to the patient being tested. This makes the entire system closed loop and forms an optimally matched filter system, as described by Lytle, Ref. 7.

The system design shown in Figure 2 is conceptual, has not been reduced to practice, and some modifications might be required. The diagnostic assist capability of the system could be extended by using additional delay lines to establish the cross-correlation between signals generated by a given patient and signal patterns known to be characteristic of some specific disease or malfunction. Reduced to practice, the system should provide EEG traces that contain more significant information and less noise than the traces presently used for diagnosis.

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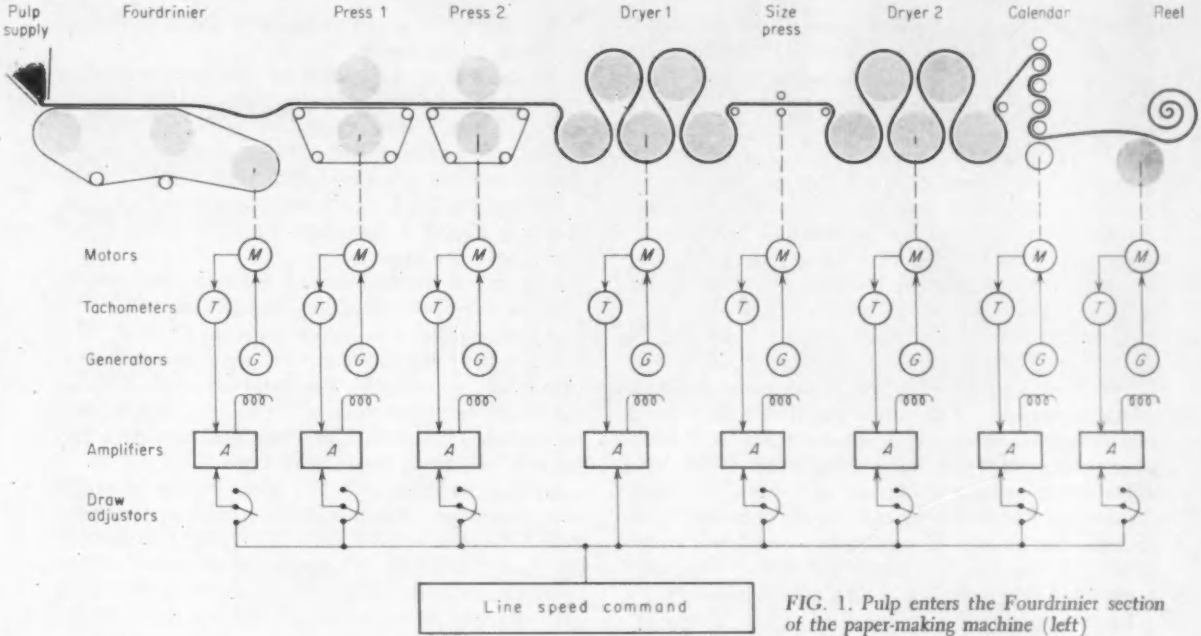

FIG. 1. Pulp enters the Fourdrinier section of the paper-making machine (left) and emerges as a reel of paper (right).

Operational Amplifier Improves Speed Regulator

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THE GIST: A speed regulation system is given high open-loop gain, fast response, and stability by employing an operational amplifier to preamplify speed error signals. Other advantages derive from the transistorized circuitry of the amplifier—freedom from drift eliminates the need for adjustment, and the plug-in design simplifies maintenance and lessens mill downtime. Long life is anticipated, even in the corrosive environment of a paper mill.

In the production of paper, high accuracy speed regulation is required. As shown in Figure 1, the sheet is first formed from wet pulp on the wire-cloth Fourdrinier section, then passed through succeeding sections, getting dryer as it goes, and finally wound up at the reel. The weakness of the sheet requires careful maintenance of speed at each section to prevent breakage. Pulling out an unstretched element of dry paper by 0.5 in. per 100-in. length can break it. Speed at each section must be finely adjusted to set the desired tension in the paper, and speed wander must be confined to a very narrow band to avoid breaking the paper.

System performance requirements

Speed of each section is first operator-selected and then maintained by the closed-loop control system

shown in Figure 2. The operator-set command voltage is compared electrically with feedback voltage from the dc tachometer generator. The difference between the two is a voltage representing speed error. This error voltage results from changes in motor speed caused by unwanted disturbances such as motor loading and shifts in line voltage and frequency. Amplified, such an error voltage changes dc motor terminal voltage to eliminate speed error.

Once the machine operator has set section speeds to produce proper sheet tension, it is up to the regulators to hold these within the limits described. The surface velocities of the section rolls will be set at different values since tension is determined by "draw", or percent speed differential between adjacent sections. Production speed of a machine is often changed by raising or lowering the basic reference voltage fed to all section regulators. The draw adjustments are trimmings of this signal. Unless the average input error to each regulator is very close to zero, the change in production speed will upset section draws, and the sheet will break. This imposes a rigid requirement on the amplifier design.

From experience in operating paper machines, it has been determined that section speed should be maintained to an average accuracy of better than 0.1 percent of top speed. Over a period of several days, average speed should not move from the operator's setting by more than 1 fpm on a 1,000 fpm machine. Momentary transients of greater magnitude may be superimposed on this, if the duration of such transients is small compared to the time it takes an element of paper to travel from section to section. Under these conditions, there is no noticeable change of sheet tension on a paper machine.

Adapting the operational amplifier

The basis of the system is a high gain error signal preamplifier that provides the bulk of the system's open-loop gain. A transistorized unit, Figure 3, was adopted from the analog computer field. Called an operational amplifier, it includes a low-drift, high gain dc amplifier with input and local feedback components.

To serve as a preamplifier in the speed regulating system, the operational amplifier should provide accurate steady state regulation and fast response to changes in command. These design objectives can be met by selecting appropriate values for the input and feedback components shown in the block diagram, Figure 3, to adapt amplifier performance to system requirements.

The first of the two desired characteristics—steady state accuracy—is obtained by devising a system that works with a low steady state input error. The magnitude of the input error is determined by two component signals: 1) the amplifier drift, and 2) the actuating signal required to support desired output speed. Both must be examined to obtain the desired low steady state input error.

Drift is undesirable in the speed regulator amplifiers, since this causes changes in the system controlled variable—paper machine speed. Extremely low drift is inherent in operational amplifier design, even though transistor operating characteristics shift with changes in temperature. Compensated input circuitry adjusts temperature-caused changes in base-to-emitter voltage and collector leakage current at the first stage. In addition, a drift-free chopper amplifier used ahead of the first dc stage reduces the uncompensated input drift at the first dc stage by the gain of the ac amplifier. By this means, drift contributes only an insignificant amount of the input error signal.

The other portion of the steady state input error signal—the actuating signal—is held at a low level by the high dc gain around the speed regulator loop. The high gain of the dc amplifier is maintained by using a capacitance in the feedback (H in Figure 3C) that effectively open-circuits feedback for dc and low frequency inputs. Using the operational amplifier without local circuit feedback brings the full 100,000 volts per microamp gain of the dc amplifier into effect. If a motor load change demands an

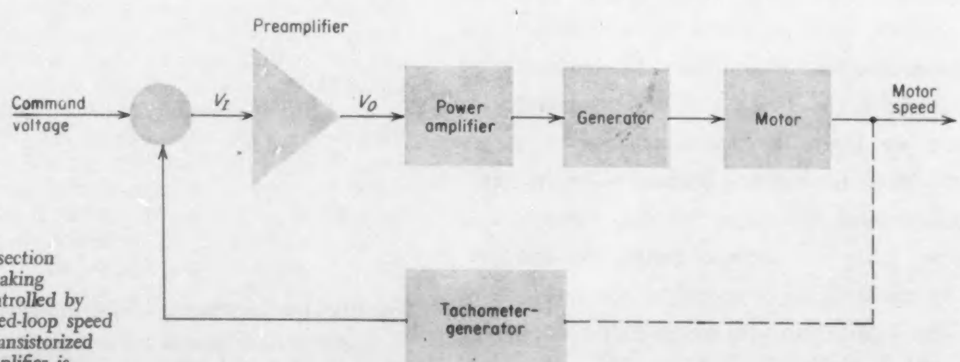
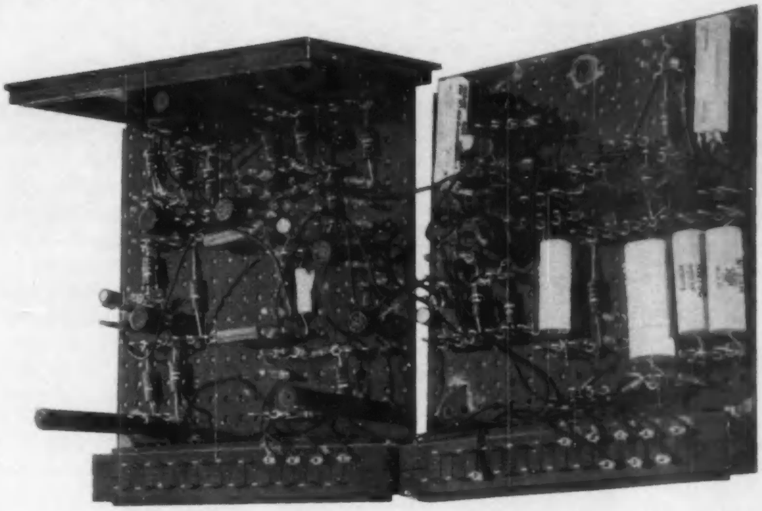
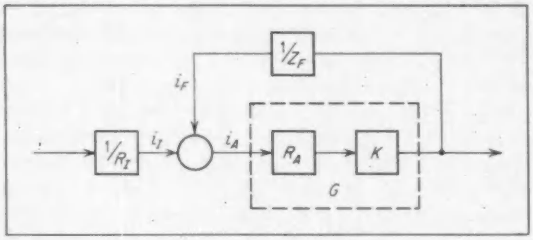


FIG. 2. Each section of the paper-making machine is controlled by a separate closed-loop speed regulator. A transistorized operational amplifier is used as a preamplifier.

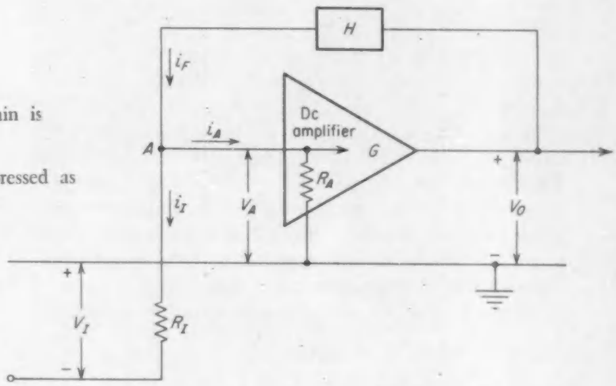
Fig. 3. The Operational Amplifier



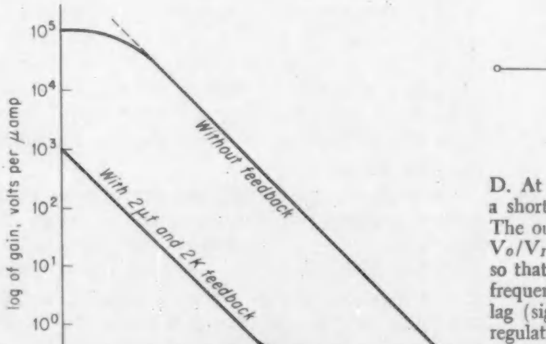
A. Built as a plug-in modular unit, the operational amplifier is easily serviced by replacement with a spare so that machine downtime is minimized.



B. Gain of the basic amplifier circuit, K, is typically 500,000 volts per volt. Gain of the dc amplifier (which includes the resistance R_A) is given by the expression G equals V_o/i_A and is 100,000 volts per microamp. Gain of the feedback circuit is the reciprocal of its impedance, Z_F, and is expressed as $H = 1/Z_F = i_F/V_o$.



C. Gain of the operational amplifier is $V_o/V_I = (1/R_I)/[G/(1 + GH)]$.
When feedback capacitance open-circuits H, gain is over 250,000 volts per volt and is expressed as $V_o/V_I = G/(R_I + R_A)$.
When feedback is significant, gain can be expressed as $V_o/V_I = Z_F/R_I$.



D. At high frequencies feedback capacitance acts like a short circuit, and feedback is a pure resistance R_F. The output voltage has a fixed ratio to input voltage, and V_o/V_I equals R_F/R_I. This is independent of frequency, so that the amplifier transmits signals of significant frequencies with constant amplification and zero phase lag (significant frequencies in an industrial speed regulating system go out to about 100 radians per sec).

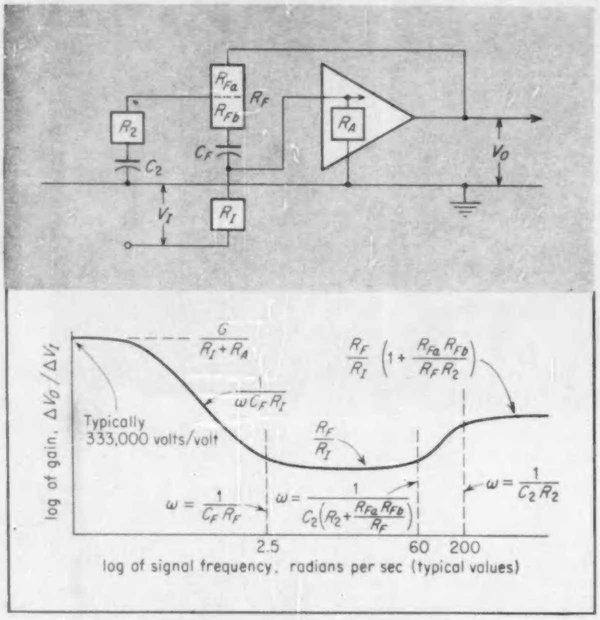
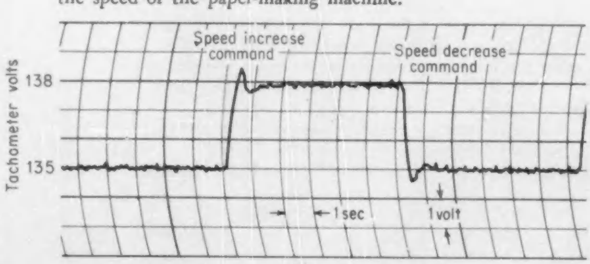


FIG. 4. Lead circuits added to the basic operational amplifier compensate for phase lags of controlled elements in the loop. Amplifier response is thus modified to satisfy the system requirements.

additional 10 volts of generator output, this would be satisfied by a steady state change in amplifier input of only 4 microvolts. This results from the operational amplifier dc gain without feedback of over 250,000 volts per volt and a power gain of 10 from amplifier output to generator voltage. The 4-microvolt error signal is 8 millionths of a percent speed error for a typical effective tachometer operating level of 50 volts. Since the regular error level is small, the dc amplifier gain can vary appreciably without introducing noticeable speed error.

As the frequency of the input signal is increased,

FIG. 5. Step command input shows the response and stability obtained in regulating the speed of the paper-making machine.



the impedance of the capacitor drops, the magnitude of the feedback signal increases, and the effective amplifier forward gain decreases. At high frequencies, the capacitor acts as a short circuit, and gain is determined by resistances in series with the capacitor, Figures 3C and 3D.

The second major requirement for the speed regulator is fast response to changes in command. This is accomplished by keeping the system loop gain as high as possible at all signal frequencies, yet progressively reducing it as frequency increases, to preserve stability. Speed of response to a step command input is closely related to crossover frequency. The time in seconds for output to reach the peak of the first overshoot after receiving the step change is roughly $3/F$, where F is the crossover frequency in radians per second.

Thus, to achieve a responsive system, the crossover frequency must be made as large as possible consistent with stability. Energy storing elements such as mechanical inertia, field inductance, and filter capacitance contribute phase lags around the loop. By counteracting such lags with corresponding leads, a high crossover frequency can be obtained.

One such lead is produced by putting a resistor in series with the feedback capacitor. At high frequencies, when the capacitor is effectively shorted, the resistance prevents feedback from becoming a short circuit and maintains amplifier gain at a constant value equal to the ratio of feedback to input resistance, Figure 3C. A second lead is provided by grounding a portion of the feedback resistor through another resistance and capacitance, as shown in Figure 4. Values are chosen so that C_F (selected to compensate for the longest lag) short circuits at a lower frequency than C_2 (selected to compensate for the next longest lag).

The longest lags in the complete system are created by the mechanical load inertia and the generator field inductance. The inertia time constant for a light paper machine section ranges from 0.25 sec to 1 sec, and for a heavy section from 2 to 6 sec. Generator field time constants vary from 0.5 to 3 sec. When the time constant of one of the lags in a linear system is equaled by the time constant of a lead circuit, the two cancel each other and there is no net effect tending to change system loop gain or phase shift with frequency. These leads appear as upturns and the lags as downturns on the response diagram, Figure 4.

To evaluate the operational amplifier as adapted, system performance was examined in terms of the two major criteria (response and stability) for a speed regulating system by applying a step command at the regulator input. A speed change command was given by the operator, and a trace taken at the wire turning roll of the paper machine. The quick response and rapid settling observed, Figure 5, show the effectiveness of the operational amplifier as a speed regulating preamplifier.

Low Pressure Pneumatics for High Performance Control

THE GIST: In developing a pneumatic positional servo for vehicle power steering, the authors obtained adequate handling and tracking with only 160 psi supply pressure. The ability to use such a low pressure in this critical application should give control engineers second thoughts about low pressure pneumatics.

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High pressure (3,000 psi) pneumatic servos and new hot gas servos give accurate positioning and good dynamic performance in aerospace applications. However, little has been done with low pressure air (up to 350 psi) as a control medium, considering its wide availability in industrial areas where there is increasing need for high performance servo controls. For the most part, this need is being met with the hydraulic and electrical servos now on the market. But large cost savings could be realized by using presently available in-plant sources of low pressure air.

Another application of pneumatic servos is in commercial vehicles. Many of these contain a source of air for controlling brakes, suspensions, door openers, etc. Application of pneumatics to steering makes possible compensated systems using low power pneumomechanical computing and transducing elements. Several manufacturers have investigated pneumatic torque boosters for bus and truck steering, and using air power in a positioning servomechanism is a logical extension.

The system described here was designed for steering a typical American passenger car. This vehicle lends itself to analytical studies, since its characteristics have been well defined mathematically. Major emphasis was placed on geting satisfactory operation at minimum operating pressure. Extension of the results to larger commercial vehicles should be straightforward.

Comments on vehicle steering

Figure 1 shows a typical manual steering system in functional form; Table I gives the nomenclature. To simplify analysis, all parameters are related to the pitman shaft so that a one-to-one correspondence exists between δ_{SW}, δ_P, and δ_{FW}. By relating tire slip angle to δ_{FW} it is possible to come up with an expression for aligning torque AT. The dynamic terms have a secondary effect and can be neglected.

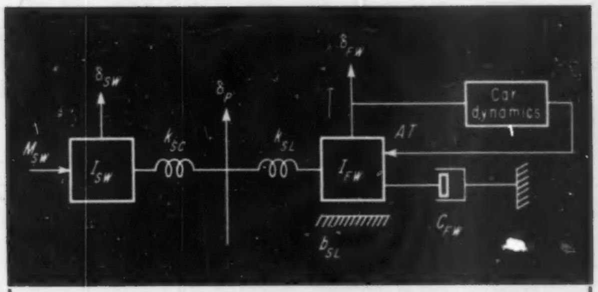


FIG. 1. Manual steering system in functional form; see Table I for nomenclature.

TABLE I
NOMENCLATURE FOR FIGURE 1

AT	Aligning torque at front wheels, in.-lb
b_{SL}	Steering linkage coulomb friction reflected to pitman gear, 174 lb
C_{FW}	Front wheel viscous friction reflected to pitman gear, 700 lb/in./sec
I_{SW}	Steering wheel inertia, lb-in.-sec^2
I_{FW}	Front wheel inertia, lb-in.-sec^2
k_{SL}	Steering linkage stiffness reflected to pitman gear, 44.8×10^3 lb/in.
k_{SC}	Steering column stiffness, in.-lb/rad
k_{FW}	Aligning torque stiffness reflected to pitman gear, lb/in.
M_{SW}	Steering wheel hand torque, in.-lb
δ_{SW}	Steering displacement reflected to servovalve, in.
δ_P	Pitman displacement reflected to pitman gear, in.
δ_{FW}	Front wheel displacement reflected to pitman gear, in.

For steady state, aligning torque is given by

$$AT = k_{FW}\delta_{FW} \quad (1)$$

where k_{FW} is the aligning torque stiffness term and varies directly with car speed.

Positioning resolution becomes important at high speeds because the steering angle for a constant side acceleration decreases. At 90 mph, a front wheel angle of 1.7 deg produces a side acceleration of 0.6 g, close to the maximum safe value. Resolution can be determined quantitatively by assuming that deadband causes a maximum side acceleration error of 0.03 g (0.96 ft per sec^2). This gives a maximum front wheel angle deadband of 0.08 deg which requires that steering resolution at 90 mph be 5 percent of the 1.7 percent value. Assuming a 2-ft lateral drift as maximum before the driver corrects his course, he would be correcting at a maximum rate of once every 2.0 sec.

The dynamics between front wheel displacement and yaw rate are quite slow; as a function of sinusoidal input to the front wheels, the yaw rate output is flat to 1 cps and then drops off. The manual steering link is relatively stiff, having a natural frequency of 7.0 to 8.0 cps; this is related to wheel fight and shimmy, not to improved car response. The driver himself is severely limited by velocity requirements and inertia reactions. In fact, the vehicle response overtaxes the driver's dynamic capability. Therefore, it appears that a steering control system with a response flat to 2.0 cps would be more than satisfactory.

Design specifications

Minimum servo requirements are as follows: specifications are referenced to the pitman shaft for a normal linkage ratio to the wheels of 1.12:1.

- Maximum quasi-static load—7,750 in.-lb. (corresponding to about 50 lb at the steering wheel rim of a car equipped with a manual steering system.
- No-load servo velocity limit—45 deg per sec.
- Peak servo displacement—plus or minus 42.5 deg.
- Minimum servo resolution—plus or minus 0.04 deg.
- Response from driver to front wheels—flat to 2.0 cps and no appreciable overshoot at car speeds over 10 mph.

Another important specification is servo inverse stiffness. Applied to the vehicle, this is the relationship between front wheel deflection and input torques caused by road irregularities. Some minimum of rigidity is needed to prevent shimmy and wheel deflection when crossing railroad tracks, holes, etc. Pneumatic actuators are inherently compliant, and while closed-loop control greatly increases their inverse stiffness, dynamic compliance could still be too high. Therefore, a variable rate damper that could be adjusted during road evaluation for proper wheel dynamic stiffness was provided.

Coulomb friction in pneumatic servos is far more detrimental to performance than in hydraulic systems. While this is hard to translate into a servo specification, all hardware was designed to minimize friction wherever possible.

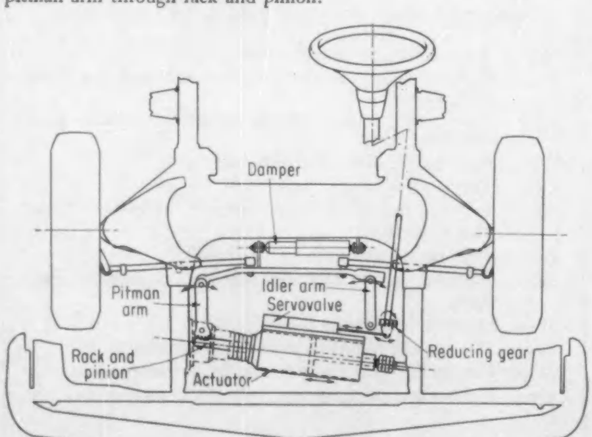
Mechanical details

The car installation, Figure 2, was made as conventional as possible. The steering wheel is connected to a servo valve linkage through a standard gear box having a 20:1 ratio. Rotating the steering wheel displaces the valve spool, sending air to the actuator. Actuator motion then turns the front wheels and moves the valve sleeve so as to reduce the flow of control air to zero. Since front wheel displacement is directly determined by valve spool position, there is no mechanical link connecting the driver to the front wheels; the driver feels no road forces and must recenter the steering wheel when coming out of a turn. An accessory unit (not shown) provides a small centering force and reflects road force to the driver. Control ratio is standard with 5.5 turns of the steering wheel from lock to lock.

The pneumatic actuator operates the pitman arm through a rack and pinion; the pinion is an integral part of the pitman shaft, and the rack is connected to the end of the actuator housing. Reaction force is taken by the chassis frame to which the actuator piston shaft is connected. Unbalanced pressure on four pistons generates a force that causes the actuator body to move and steer the front wheels. The servo valve is a typical 4-way spool valve; it is attached to the actuator housing, giving a feedback ratio of 1:1.

Turning the steering wheel with the servo deenergized produces large relative motions between valve spool and sleeve. To limit this relative travel to a reasonable value, an overtravel unit is incorporated as part of the spool linkage. A ball detent

FIG. 2. Pneumatic actuator operates pitman arm through rack and pinion.



arrangement within the overtravel unit provides a solid mechanical connection to the valve spool until overtravel is effected and the detent releases. If springs alone had been used to take up overtravel, undesirable spring deflections would have caused increased deadband and dynamic lag.

The viscous damper shown in Figure 2 is a modified automotive shock absorber with special valving that allows a wide variation in damping characteristics.

Dynamic analysis of pneumatic servo

LINEAR ANALYSIS: While a linear mathematical analysis is valid only for small signal operation about the actuator center position, it does allow the time constants, natural frequencies, and damping factors to be expressed directly in parametric form for optimizing dynamic performance.

Figure 3 shows the elemental parameters that determine the servo dynamics. In the analysis that follows, all parameters (see Table II for new nomenclature) have been referenced to the pitman gear circumference which has a 1.5-in. radius. The open-loop servo equation can be written in terms of natural frequencies and damping factors as

$$\frac{Y}{X} = \frac{K_1\left(\frac{D^2}{\omega_1^2} + \frac{2\zeta_1}{\omega_1} D + 1\right)}{D\left(\frac{D^2}{\omega_2^2} + \frac{2\zeta_2}{\omega_2} D + 1\right)} \tag{2}$$

where $$K_1 = \frac{Ak_1(k_{SL} + k_{FW})}{A^2(k_{SL} + k_{FW}) + k_{SL}k_3k_{FW}} \tag{3}$$

$$\omega_1 = \left(\frac{k_{SL} + k_{FW}}{m}\right)^{1/2} \tag{4}$$

$$\zeta_1 = \frac{\omega_1}{2}\left(\frac{C_{FW}}{k_{SL} + k_{FW}}\right) \tag{5}$$

$$\omega_2 = \left[\frac{k_{SL} + k_{FW} + \frac{k_{SL}k_3k_{FW}}{A^2}}{m\left(1 + \frac{k_{SL}k_3}{A^2}\right)}\right]^{1/2} \tag{6}$$

and $$\zeta_2 = \frac{\omega_2}{2}\left[\frac{C_{FW}\left(1 + \frac{k_{SL}k_3}{A^2}\right)}{k_{SL} + k_{FW} + \frac{k_{SL}k_3k_{FW}}{A^2}}\right] \tag{7}$$

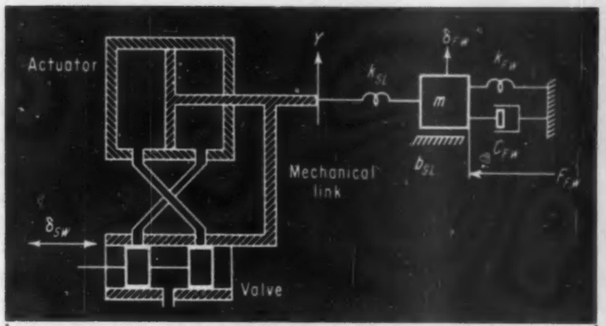


FIG. 3. Valve, actuator, and parameters that influence servo dynamics.

TABLE II
NOMENCLATURE FOR DYNAMIC ANALYSIS

A	Actuator piston area, 78.5 sq in.
D	Derivative operator, 1/sec
F_{FW}	Road disturbing force at front wheels, lb
k_1	Valve no load flow sensitivity, in.^{2}/sec
k_3	Actuator fluid compliance, 0.457 in.^{5}/lb
K_1	Open-loop velocity gain, 1/sec
m	Front wheel inertia reflected to pitman gear, 12.8 lb/in./sec^2
V	Car road velocity, mph
X	Relative displacement between valve spool and sleeve, in.
Y	Actuator displacement, ±1.25 in. max.
ω	Natural frequency, rad/sec
ζ	Damping factor
τ	Time constant

Due to the sonic flow characteristics of pneumatic servovalves, small changes in load pressure have little effect on flow and negligible influence on servo operation. This accounts for its omission in the equations.

To maximize servo stability, ω_1 must be approximately equal to ω_2. With a given supply pressure, this means making piston area A as large as possible. Since k_{FW} is velocity sensitive, the parameters of Equation 2 vary with car velocity; Table III shows the range encountered.

A car velocity of 1.0 mph represents the critical

TABLE III
EQUATION 2
PARAMETERS FOR
THREE CAR SPEEDS

V, mph	k_{FW}, lb/in.	ω_1, rps	ζ_1	ω_2, rps	ζ_2	K_1, 1/sec
1	0	59.3	0.463	28.4	0.955	$0.0127k_1$
35	14,200	68.2	0.402	44.1	0.617	$0.007k_1$
90	30,000	76.5	0.70	56.2	0.501	$0.0055k_1$

point of servo stability because ω_1 and ω_2 are minimum and have the greatest spread, and open-loop gain K_1 is maximum for a given no load flow sensitivity k_1. Fortunately, steering requirements are minimal at this low speed. As speed increases, response becomes more critical, but servo stability and closed-loop transient performance also improve.

Servo stability as a function of open-loop gain can be studied using the Bode technique. Figure 4 is a plot of Equation 2 at 1.0 mph velocity. Phase shift never exceeds 150 deg, indicating that the system should always be stable. However, the steep attenuation slope could produce undesirable transient overshoots. A desirable operating point would be at $K_1 = 20$.

Closed-loop servo performance can be studied by relating front wheel deflection to steering input and road disturbing forces as follows:

$$\delta_{FW} = \left[\frac{\delta_{FW}}{\delta_{SW}}\bigg|_{ss}\right] \frac{1}{\left(\frac{b_3}{b_0}D^3 + \frac{b_2}{b_0}D^2 + \frac{b_1}{b_0}D + 1\right)} \delta_{SW}$$

$$- \left[\frac{\delta_{FW}}{F_{FW}}\bigg|_{ss}\right] \frac{(1 + \tau_1 D)}{\left(\frac{b_3}{b_0}D^3 + \frac{b_2}{b_0}D^2 + \frac{b_1}{b_0}D + 1\right)} F_{FW} \qquad (8)$$

where $b_3 = m(A^2 + k_{SL}k_3)$ (9)

$b_2 = C_{FW}(A^2 + k_{SL}k_3) + Ak_1m$ (10)

$b_1 = A^2(k_{SL} + k_{FW}) + k_{SL}k_3k_{FW} + Ak_1C_{FW}$ (11)

$b_0 = Ak_1(k_{SL} + k_{FW})$ (12)

$$\tau_1 = \frac{k_{SL}k_3 + A^2}{Ak_1} \quad \text{and} \qquad (13)$$

$$\frac{\delta_{FW}}{\delta_{SW}}\bigg|_{ss} \text{ and } \frac{\delta_{FW}}{F_{FW}}\bigg|_{ss} = \text{steady state solutions}$$

The δ_{SW} term represents the input-output **transfer** function, while the F_{FW} term shows the influence

FIG. 4. Phase shift stays in stable range, but steep attenuation slope indicates possibility of overshoots.

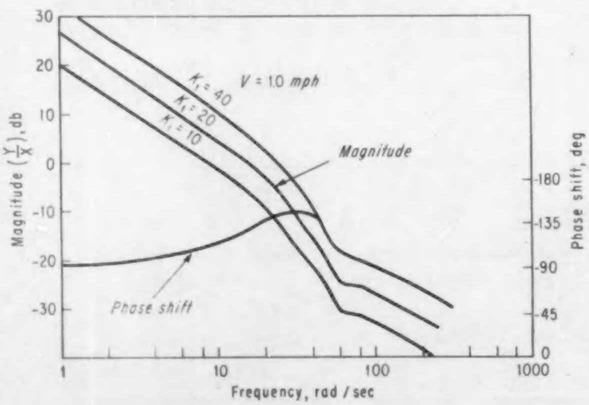


TABLE IV

ROOT MAGNITUDES FOR EQUATIONS 13, 15

V, mph	τ_1, sec	τ_2, sec	ω_3, rps	ζ_3
1.0	1/4.65	1/43	19	0.43
35	1/4.65	1/44	39.6	0.57

of disturbing forces caused by the road. For steady state, Equation 8 becomes

$$\delta_{FW} = \frac{\delta_{SW}}{1 + \frac{k_{FW}}{k_{SL}}} - \frac{F_{FW}}{k_{FW} + k_{SL}} \qquad (14)$$

which points up the importance of steering linkage compliance.

The polynomial denominator term in the δ_{SW} expression of Equation 8 determines dynamic performance. Roots of this polynomial, see Table IV, were found for K_1 equal to 20 and k_{FW} values representing 1.0 and 35 mph. Modification of the polynomial to show the roots is

$$\left(\frac{b_3}{b_0}D^3 + \frac{b_2}{b_0}D^2 + \frac{b_1}{b_0}D + 1\right) = (1 + \tau_2 D)\left(\frac{D^2}{\omega_3^2} + \frac{2\zeta_3}{\omega_3}D + 1\right) \qquad (15)$$

Plots of this data for steering response show slight peaking at 1.0 mph which will result in a small transient overshoot. At 35 mph and above, the gradual roll off will produce an exceptionally smooth control system. Time constant τ_1 determines the amplification of front wheel deflections caused by road forces. Its large value indicates that wheel shimmy may be a problem.

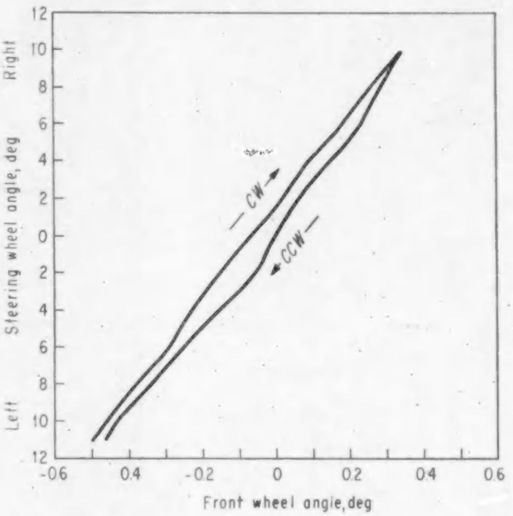
NONLINEAR ANALYSIS: The linear analysis is based on several simplifying assumptions, and response studies with large input signals dictate the use of a more exact mathematical model. Nonlinearities that should be included are:

- Servovalve deadband and maximum weight rate of flow limit.
- Variation of coefficients for the differential equations describing actuator operation.
- Coulomb friction at the front wheels.

System equations including these nonlinearities were programmed on an analog computer to obtain the required solutions. The analog model was verified by cross checking the model's sinusoidal responses at small signal amplitude with those obtained in the linear analysis. Correlation was good except that the model's closed-loop response was slightly lower. With an open-loop gain of 40 instead of 20, overshoots were appreciably attenuated at road speeds greater than 35 mph.

Experimental Data Shows Good Response, Resolution

FIG. 6. Steering resolution tests showed maximum front wheel deadband of 0.062 deg.



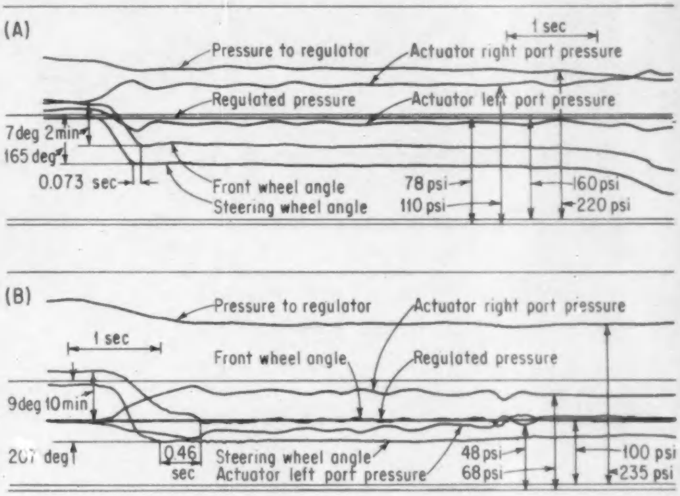


FIG. 5. Front wheel response to right turn step input signal with supply pressure of 160 psi (A) and 100 psi (B); car speed was 30 mph.

Experimental results

Dynamic response of the pneumatic servo steering unit was quite good; Figure 5A shows front wheel response during a rapid right-hand turn. To achieve this performance it was necessary to modify some initial design parameters. In the theoretical analysis it was pointed out that the inverse dynamic stiffness might be too low, and this turned out to be the case. Front wheel oscillations induced by road forces were quite marked with a servo open-loop gain of 20 and operating at 100 psi supply pressure; wheel shimmy could develop when driving at low speeds on rough roads.

By making the following changes, front wheel dynamic stiffness was raised to a satisfactory level:

1) Open-loop servo gain increased from 20 to 40.

2) Supply pressure raised from 100 to 160 psi.

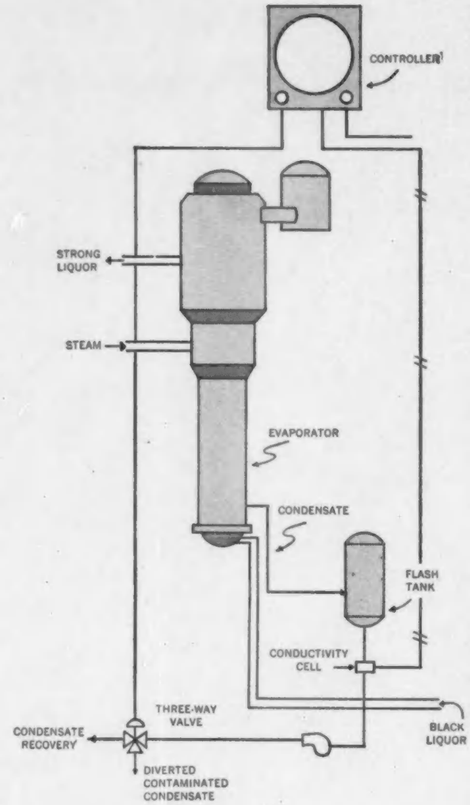
3) Viscous damping equal to 1,060 lb per in. per sec added at front wheels.

Changes 1 and 2 increase the inverse static stiffness directly, while change 3 improves stiffness by increasing the viscous force reaction at the front wheels. The proper amount of added viscous damping was found by trial and error; the valving of a take-apart shock absorber was varied to get the proper steering characteristics. Data for Figure 5A were obtained with these modifications.

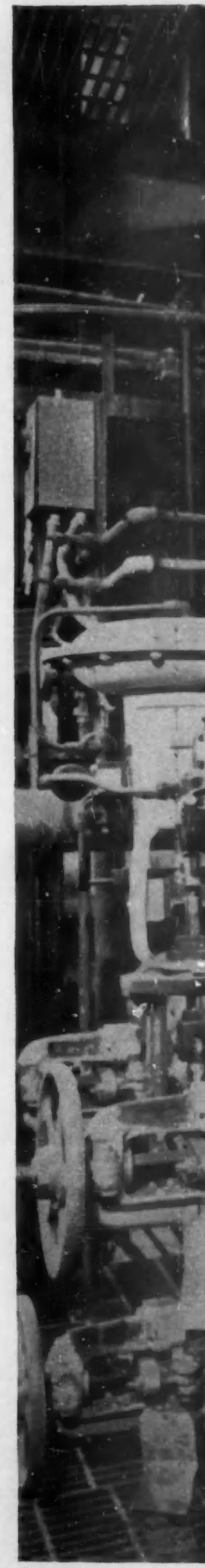
During the preliminary investigation, emphasis was placed on operating at 100 psi supply pressure. But in the experimental work it was dramatically evident that a higher supply pressure was essential for proper operation. This is brought out by Figure 5B, taken under the same conditions as Figure 5A except for the 100 psi supply pressure. The completely unsatisfactory over-damped response is evident. Also, the small oscillations in the front wheel trace indicate that the inverse dynamic stiffness is not sufficient, and that even more viscous damping at the front wheels is needed.

Driver evaluation of steering resolution indicated that vehicle tracking response to small steering wheel displacements was excellent at all road speeds up to the maximum test speed of 80 mph; there is no reason to expect unsatisfactory performance at higher speeds. This qualitative judgment was substantiated by static resolution measurements made with the car standing still, its front wheels off the ground. Figure 6 shows front wheel displacement as a function of steering wheel rotation; maximum front wheel deadband is 0.062 deg, which is within the design specification of plus or minus 0.04 deg pitman arm rotation.

An interesting aspect of pneumatic servo steering is that vehicle course deviations caused by side winds and road irregularities are less pronounced than with conventional steering. The pitman arm is kept at a given position by closed-loop servo action; thus, the steering system from the pitman arm back to the driver has theoretically infinite stiffness. Front wheel deflections caused by road or wind inputs are limited by the steering linkage compliance.



The Honeywell Three-Way Diverting Valve shown on the opposite page safeguards plant equipment at St. Regis Paper Company in Tacoma, Washington. Located in the steam condensate line leading from the multi-effect black liquor evaporator, the valve protects vital boiler tubes and pipes by diverting contaminated condensate. Contamination resulting from the presence of black liquor in the condensate is detected by a conductivity cell. When the concentration passes safe limits, a Honeywell *ElectroniK 15* Controller signals the valve to divert the contaminated condensate.



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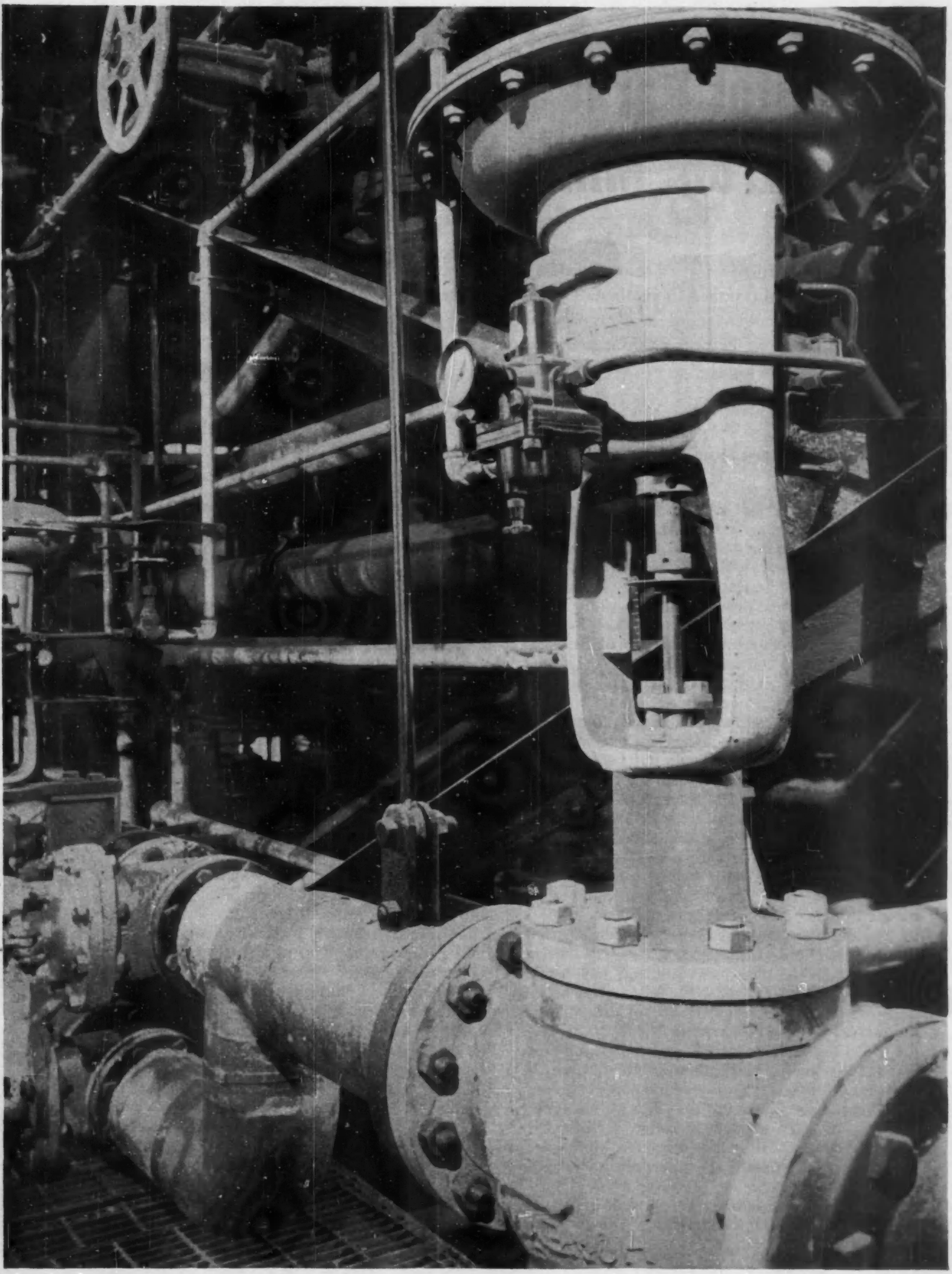

Digital Parabolic Interpolator Controls Milling Machine

THE GIST: This numerical control system accepts a workpiece description as input and produces a continuous path output for machining marine propeller blades. It is distinguished by parabolic interpolation, a fixed program for path control, and a large buffer store.

SJ. TYSMA,
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Working from a 60 ft long punched tape, an unusual special-purpose numerical control system steers a ball cutter through space to completely machine small marine propellers. The propeller shape is defined in a cylindrical coordinate system and is cut one blade at a time, as shown in Figure 1. During cutting, the vertical and rotating machine motions are continuously controlled, and the horizontal axis is held constant during any pass around the blade surface. At the completion of a pass, the cutter moves an increment inward, toward the hub center, and then another loop begins around the blade. This loop-and-step-inward pattern of movement continues until one blade has been entirely contoured. The workpiece is then indexed through an angle and the next blade machined.

The actual shape of the blade is stored on the input tape, and not the incremental cutter "departure distances". Absolute coordinates for the angle, radius, and height of a point are punched in binary on the tape. Using coordinate gridlines 0.2 in. apart, about 2,000 gridpoints suffice to define a medium size propeller of around 10-in. OD. The data points supplied to the control unit do not actually lie on the surface of the blade, but instead form an envelope enclosing the blade, equidistant from the true blade surface by an amount equal to the cutter's radius. For economy of tape handling, the barest minimum of data is supplied on the tape. The blade's leading and trailing edges are given in $r\theta$, the gridlines of a reference datum plane are given, and the vertical values of the offset cutter center location are given as some distance, z, from this plane. From such relatively unrefined input data, the control unit generates the cutter path from fixed-program internal logic.

Data for a four-gridline span of blade shape are fed from the tape into a buffer store. The words are 17 bits long, and 320 are required to describe the four-gridline piece of blade. Parabolic interpolation is used to calculate the cutter-center location between the gridpoints fed into buffer storage. Interpolation is based on the Gregory-Newton formula (see CtE, Sept. '58, p. 153 and June '57, p. 114), using a 3 by 4 matrix as shown in Figure 1. Each point lies some distance, z, from the reference datum plane. Two interpolation factors, α and β, determine the closeness of interpolated points between the given gridpoints. The radial interpolation factor, β, corresponding to the machine's horizontal axis, is held constant for each pass around the blade. From four sets of three points given in the matrix, and β, four z_β values are determined in the first (shaded) radial interval. The tangential interpolating factor, α, corresponding to the machine's rotating axis, is used with the z_β values to determine the required Z value in the second (shaded) tangential interval. This final Z value is the interpolated signal that drives the machine's vertical axis. The organization of the required supervisory, arithmetic, and servo functions is shown in Figure 2.

Supervisory logic governs mainly the fixed-program aspects of the system, operation of the tape reader, and transfer of information from buffer storage. Blade reversal point in the cutter loop is signaled from a comparison of the $r\theta$ signal representing the computed tangential cutter position and the $r\theta$ reversal point held in store. Upon completion of a loop about the blade (signaled by comparing counts in the $r\theta$ register) an additional signal feeds into the β register and the value of β changes. When the β register accumulates to overflow, the cutter is following a gridline and the tape transport is triggered to feed more gridline data into buffer store.

The arithmetic section works within the framework established by the fixed program, providing interpolated signals to the servo loops. In the arithmetic section, the first action is to extract the data establishing a 3 by 4 matrix from buffer store, and in the first, or radial, interpolator, combine this with

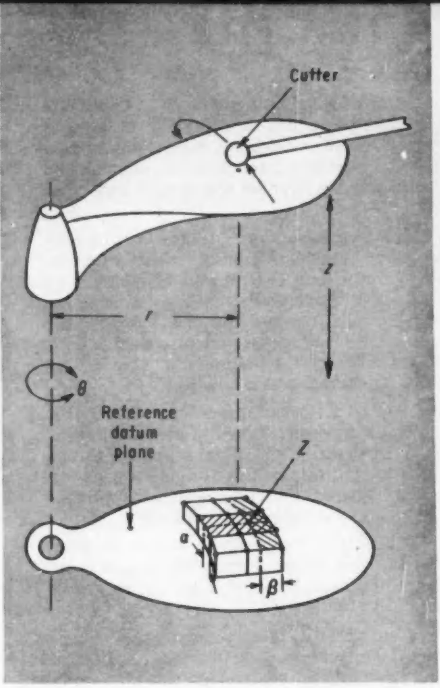

FIG. 1. The control unit guides a ball cutter in successive paths around a propeller blade. Machine axes θ and z vary continuously, r is held constant during a pass. Parabolic interpolation (below) uses 12 points some distance z from a reference datum plane.

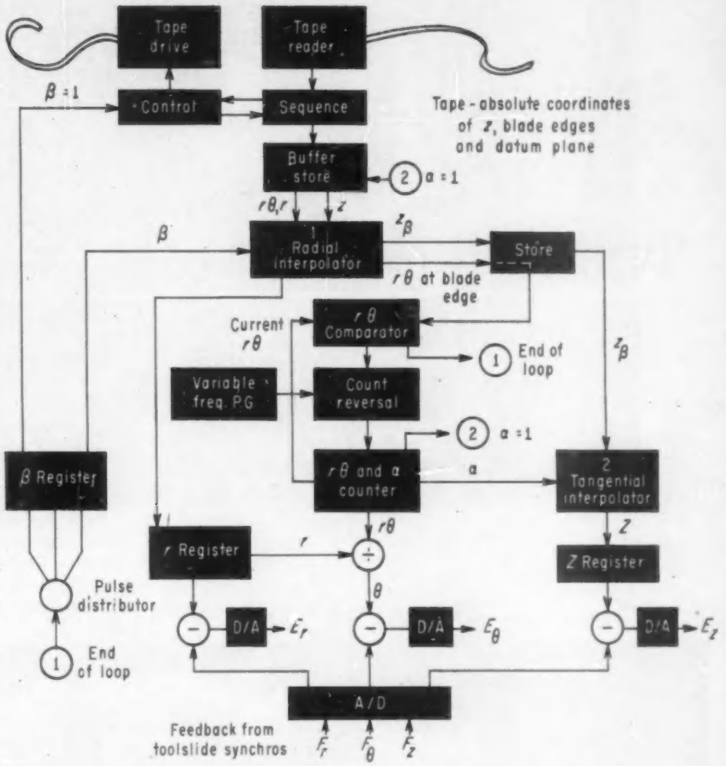

FIG. 2. The vertical coordinate z is first interpolated at some distance β from a radial gridline. Output from this first radial interpolation is four z_β values that are combined with a continuously varying α in the tangential interpolator. When the loop around the blade is complete, β is increased, starting another loop of parabolic interpolation.

the fixed β value. Output of this interpolator is four z_β values that are dumped into a store, in reserve for the second, or tangential, interpolator. During this time, a counter driven by the tangential feed rate pulse generator produces an increasing α signal. The varying α, denoting the relative position of the required point between two gridlines, is interpolated with the four z_β values to produce a parabolically varying Z output. When the value of α equals the value of the adjacent $r\theta$ gridline, signaled by counter overflow, fresh z data is dumped into a radial interpolator from buffer store. This sequence repeats till the $r\theta$ comparator signals that the cutter path is calculated to the blade edge. At the blade edge, count reversal occurs, and the system calculates a cutter path back across the blade underside to the beginning blade edge. The $r\theta$ comparator then issues an end-of-loop signal that is fed into the β register, causing an incremental increase in the value of β. Successive loops are interpolated in this fashion, each time increasing the value of β by an increment. When the value of β reaches unity, the tape reader feeds a new set of reference data into buffer store for the next four-line span.

The three outputs to the servos are r, the radial distance from the propeller hub center (machine horizontal axis), θ, the table rotation, and z, the machine's vertical axis. The z and r signals are generated directly by the interpolator; the θ signals are obtained from a simple dividing circuit. These three digital command signals feed error registers that are simultaneously fed with a digital feedback signal; error registers sum the difference between command and feedback and drive the appropriate machine axis through digital-to-analog converters. Position feedback from coarse/fine synchros is converted through a single analog-to-digital converter, scanning of the three feedback signals being controlled by the arithmetic unit.

This transistorized control unit employs wired ferrite cores for storage and programs. At setup, the machine operator sets a selector switch indicating the number of blades on the propeller—operating from this and a spliced tape loop, the unit controls machining of the entire propeller. When installed at the Netherlands Ship Model Basin at Wageningen, it will machine blades in one day instead of two weeks, and to an accuracy of 0.0012 in.

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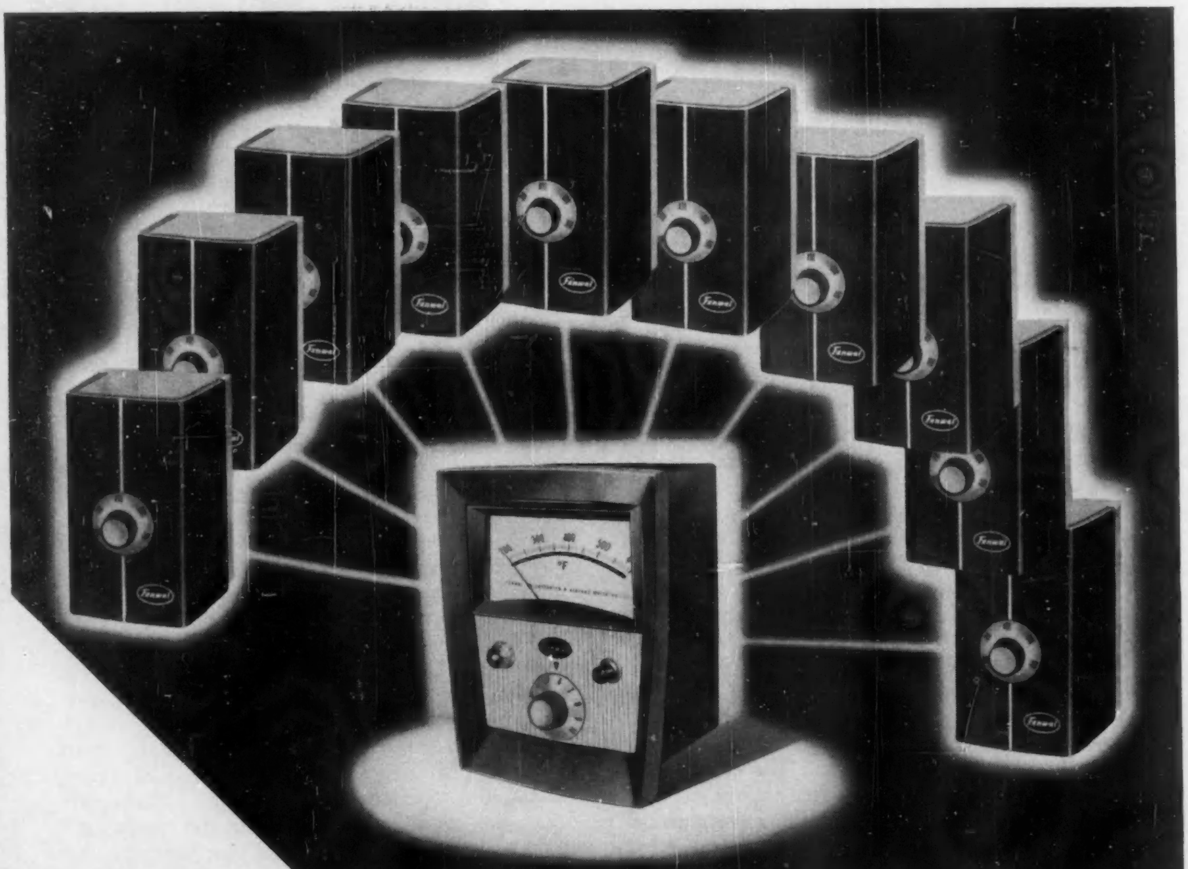

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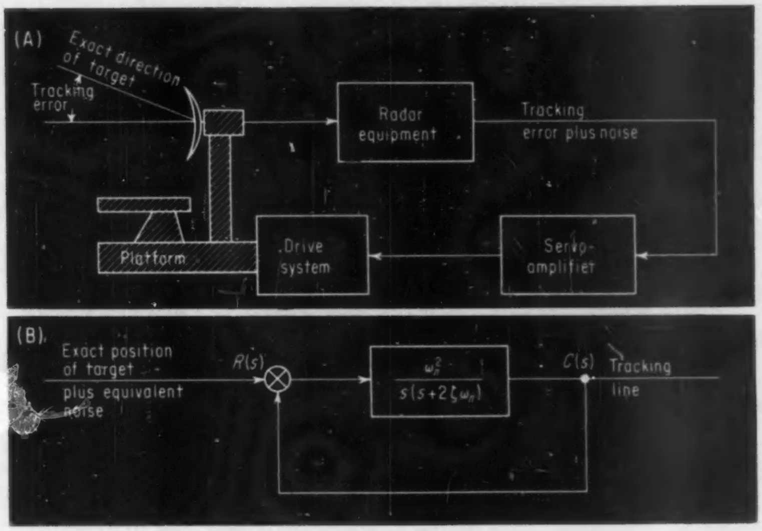


FIG. 1.

A—Radar directed fire control system used as example.

B—Equivalent servo diagram of the system.

Analyzing Random Signals in Linear Systems

MARVIN P. PASTEL
Nortronics, Div. of Northrop Corp.

Modern, high performance control systems require accurate analyses of the effects of input noise and spurious disturbances. Since noise and disturbances are generally random in nature, their effects on the control system cannot be analyzed by conventional control theory techniques. Nevertheless, when considering systems with random inputs, two important questions must be answered: 1) What system response will result? and 2) What system modification is needed to reduce the dynamic error? Author Pastel shows how to answer these questions for linear systems in this article. An upcoming article will deal with nonlinear systems.

In recent years research effort to answer the questions posed at left has resulted in a substantial body of design and analysis theory for control systems making use of statistical principles (Refs. 1, 2, and 3). This approach does not attempt to represent the random signal as a predictable function of time but describes it in terms of statistical quantities and signal averages over all time.

The required statistical theory to handle the usual control problem is gratifyingly limited and straightforward. There is a brief introduction to the statistical quantities and concepts pertinent to the following discussion on page 88.

The system to be analyzed, Figure 1, is a fire control system in which the direction of a gun is controlled by signals from a tracking radar. Of primary concern are the followup errors due to the prescribed command from the radar and the errors due to the contaminating noise. For simplification the equivalent system of Figure 1B will be studied and considered linear and adequately described by a second order transfer function:

$$\frac{C}{R}(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \tag{1}$$

The input signal in the absence of noise will be considered a ramp with transform

$$R(s) = \frac{A}{s^2} \tag{2}$$

which is contaminated with noise assumed to be

statistically Gaussian and with a power density spectrum defined by

$$\Phi_{NN} = \frac{N^2}{2} \tag{3}$$

Because the system is linear, the contributions of signal and noise to the system error can be determined individually, and they can be then added to give the total error.

The steady state error of the system to a ramp is

$$e_R = \frac{2\zeta A}{\omega_n} \tag{4}$$

Although it is impossible to give a time description to the random signal, the average (or expected) value and the mean square value of the noise can be calculated. The average values will then be accepted as an adequate description of the effect of the noise signal on the system. Generally, as in this case, the mean value of the random signal is zero or, once known, can be compensated for in the system design. Even though the mean square noise enters the followup loop at the same input as the command signal, any system response to the noise is undesirable and must be considered an error. Hence, as defined in the section of page 88 the power-density spectrum of the system output noise is

$$\Phi_{ON}(\omega) = \Phi_{NN}(\omega)\left|\frac{C}{R}(j\omega)\right|^2$$

$$= \left|\frac{\omega_n^2 \dfrac{N}{\sqrt{2}}}{(j\omega)^2 + 2\zeta\omega_n(j\omega) + \omega_n^2}\right|^2 \tag{5}$$

and the value of the mean square output can be determined by integrating this power spectrum over all frequencies and dividing the result by 2π:

$$\overline{e_N^2} = \frac{1}{2\pi}\int_{-\infty}^{\infty}\left|\frac{\omega_n^2 \dfrac{N}{\sqrt{2}}}{(j\omega)^2 + 2\zeta\omega_n(j\omega) + \omega_n^2}\right|^2 d\omega \tag{6}$$

At first hand the evaluation of this integral may appear formidable. Actually it can be handled in a straightforward fashion with application of the special integral forms given in Reference 4. Thus, the mean square value of the error due to the noise is

$$\overline{e_N^2} = \frac{\omega_n}{8\zeta} N^2 \tag{7}$$

With the value of ζ fixed to satisfy transient response characteristics (not here considered), Equations 4 and 7 present a conflict in the selection of the system's natural frequency. The output due to noise can only be reduced by reducing ω_n. But this conflicts with the requirement that ω_n be large for a small velocity lag error. Thus a compromise is in order, and to aid in making the compromise a performance criterion must be selected. Since only the mean square value of noise error is known, it will be most convenient for the performance criterion to be the minimum mean square of the total error. Dropping the product term gives

$$\overline{e_T^2} = e_R^2 + \overline{e_N^2} \tag{8}$$

The product term containing noise and signal error is zero since it is assumed that the signals are uncorrelated and hence their product averaged over all time is zero. The minimum value of $\overline{e_T^2}$ can be determined by differentiating with respect to ω_n and setting the result to zero. The value of ω_n for a minimum square total error is

$$\omega_n = 4\zeta\left(\frac{A}{N}\right)^{2/3} \tag{9}$$

For this system Equations 8 and 9 represent the answers to the questions asked at the start. Now the steps and assumptions leading up to these equations and the general applicability of this method of analysis to other systems should be considered. The linear model assumed for the system, the error criterion, the derivation of the power density spectrum, and any limitation of the analysis that may be caused by saturation are covered next.

Choice of system model

The choice of a second-order system for the example was for convenience rather than any theoretical limitation in the method. Integral forms to the tenth order have been computed and could be extended further, but the numerical labor involved in their use is prohibitive and the results are difficult to interpret. Hence, it is advantageous to keep the model representing the system as simple as possible so long as the important dynamic features of the system are retained. Good examples of system simplification and application of this method are given in Reference 3 (Chapter 9) and also in Reference 5.

Mean square error criterion

The mean square error criterion that weights the undesirability of an error according to the square of its magnitude is certainly only one of many possible error measures. Depending upon the job a system is to perform, the mean absolute value of the error might render a better system.

In the above example the mean square criterion was convenient, since the ms error to the random signal was known. The fundamental reason for the widespread use of the ms (or rms) criterion in design analysis is not because of its intrinsic value as a criterion but because it leads to a workable analysis. However, the ms criterion with its emphasis on large errors will tend to produce a lightly damped system. As in the example where ζ was fixed before the minimum was found, this effect must be considered before a final choice is made for the system parameters. In general, the ms criterion maximum is broad; small deviations from the

maximum can be accepted for good transient response with little effect on amount of noise error.

Calculation of power-density spectrum

A useful power-density spectrum can only be derived for that class of random signal classified as a stationary process. This means that the statistical properties of the random signal do not change with time. The average and mean square values of the signal if measured at a given time (over a time interval long enough to give accuracy) will be reproduced by similar measurements at a later time. It is apparent that many physical random signals may not fit into the stationary process. Nevertheless, the assumption that a random signal is stationary provides useful information, and the analysis described here is restricted to those random signals that are stationary.

A random signal with Gaussian probability density has the property that, when passed through a linear network, the output random signal is Gaussian, although the mean square values of the input and output signals differ due to the characteristics of the network. Furthermore, the summing of two Gaussian random signals will result in a random signal which is still Gaussian. These two properties are very useful in control system analysis because they insure that, if a Gaussian random signal is applied to a system, all signals throughout the system will be Gaussian.

The power density spectrum can be determined from theoretical considerations or from experimental data (Refs. 2, 3, and 6). When employing experimental data it is often convenient to first plot the autocorrelation function; the graph is approximated by a mathematical function, and the Fourier transform is then taken to yield the power spectrum. The process is illustrated in the box at the right. If this technique is to be used often, it may be desirable to arrange equipment to convert a time signal of the data into a voltage which could be passed through a wave analyzer.

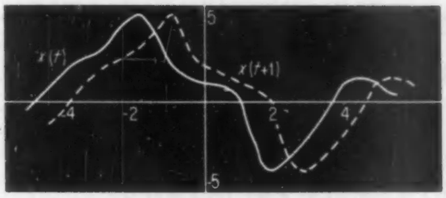
In many preliminary system studies the power spectrum is not known either because there is not enough time to reduce the data or, as is often the case, the data cannot be obtained until the system is built. Even in these cases, the assumption of a power spectrum with constant amplitude or with simple frequency characteristics will provide useful design information of the quantitative effect of the random signals and the spectrum's dependence on system parameters.

Design of complicated systems

When it is desirable to evaluate system dynamic response to a random command input rather than to a prescribed input, the input signal may be represented in terms of a power spectrum. It will generally be found that the spectrum of the command signal has low frequency components that are larger

STEPS IN DETERMINING POWER SPECTRUM DENSITY FROM EXPERIMENTAL DATA

A. Random time function



B. Numerical method of obtaining autocorrelation function

$$\phi xx(\tau) = \frac{1}{k-\tau+1}\sum_{n=0}^{n=k-\tau} X_n(t)X_n(t+\tau)$$

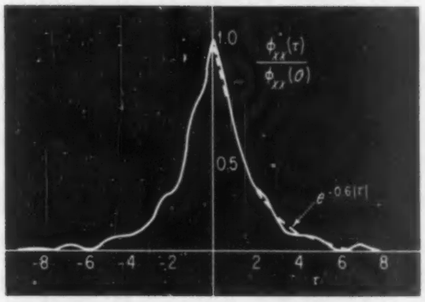
k = number of intervals; n = number of the ordinate

$$\phi xx(0) = \frac{2^2+3^2+5^2+2^2+1^2+(-4)^2+(-2)^2+1^2+1^2}{11} = 5.9$$

$$\phi xx(1) = \frac{(3)(2)+(5)(3)+(2)(5)+(1)(2)+(-2)(-4)+(1)(-2)+(1)(1)}{10} = 4.0$$

(Values where $X_n(-) = 0$ are eliminated but counted as an interval.)

C. Autocorrelation function constructed from data of A and B with dashed line representing smooth approximation $e^{-0.6|\tau|}$



D. Method of calculating $\Phi(\omega)$ from the autocorrelation function

A simple analytical expression that can be used to approximate many experimental autocorrelation functions is

$$\phi(\tau) = \phi(0)e^{-a|\tau|}\cos b\tau$$

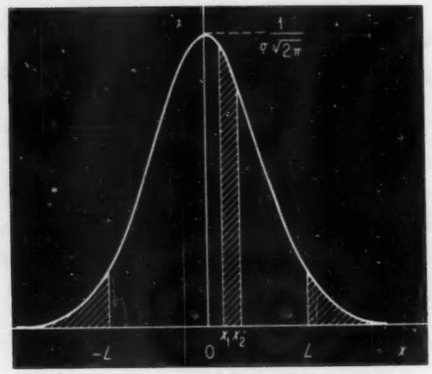
The Fourier transform of $\phi(\tau)$ gives $\Phi(\omega)$:

$$\Phi(\omega) = \int_{\infty}^{\infty} \phi(\tau)e^{-j\omega t}\,d\tau = \frac{\frac{2\phi(0)}{a}\left[1+\left(\frac{b}{a}\right)^2+\left(\frac{\omega}{a}\right)^2\right]}{\left[1+\left(\frac{b+\omega}{a}\right)^2\right]\left[1+\left(\frac{b-\omega}{a}\right)^2\right]}$$

For $a = 0.6$ and $b = 0$, then $\phi(0) = 0.59$ and $\phi(\tau) = e^{-0.6|\tau|}$

Therefore, $\Phi(\omega) = \dfrac{1.96}{1+2.78\omega^2}$

FUNDAMENTAL EQUATIONS FOR STATISTICAL TECHNIQUES IN CONTROL SYSTEMS PROBABILITY



Gaussian probability density function.

Density

A random time variable cannot be represented in the form of an explicit equation which is valid over an extended period of time. However, the randomly varying quantity can be described by various statistical relationships. Basic among these is the probability function. For a particular variable, $x(t)$, the probability function can be determined experimentally by dividing the range of values that x can assume into small increments. Then by taking a large number of samples and tabulating the results, a probability of occurrence could be assigned to the magnitudes falling within each increment. That is,

$$p(x_1 < x \leq x_2) = \frac{\begin{pmatrix}\text{number of samples with}\\ \text{values between } x_1 \text{ and } x_2\end{pmatrix}}{\text{total number of samples taken}} \qquad \text{(a)}$$

The greater the number of samples taken, the greater the accuracy of the equation.

In order to apply statistical methods conveniently to continuous functions, the probability function is usually defined in terms of a function called the probability density, $p(s)$:

$$p(x_1 < x \leq x_2) = \int_{x_1}^{x_2} p(x)\,dx \qquad \text{(b)}$$

When the probability density is known, the mean square value of a random quantity can be calculated as

$$x_{ms} = \int_{-\infty}^{\infty} x p(x)\,dx \qquad \text{(c)}$$

Gaussian density function

A general mathematical expression for a Gaussian, or normal, probability density is

$$p(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right] \qquad \text{(d)}$$

where σ is the standard deviation and μ is the mean value.

This function is shown in the figure for a mean value of zero, where the standard deviation is equal to the rms value of the random time functions and the value of the integral of Equation b corresponds to the shaded area. Since the Gaussian probability density is completely described by the standard deviation and the mean, it is a very convenient function to work with. Fortunately many random quantities encountered in control problems have probability densities that may be considered Gaussian.

Correlation functions

A further refinement in describing the statistical characteristics of a random function is the autocorrelation function:

$$\phi_{XX}(\tau) = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} x(t)x(t-\tau)\,dt \qquad \text{(e)}$$

The autocorrelation function gives some measure of the extent to which a future value of a quantity will be the same as the present value. It is important to note that by setting τ equal to zero, Equation e gives the mean square value of the random quantity.

The crosscorrelation function results when two different functions are multiplied in an expression identical in form to Equation e.

Power density spectrum

The random variable that has been described thus far in terms of its time variation may also be described in terms of its frequency spectrum. (This is strictly true only for random functions which do not change their statistical characteristics with time.) A useful function for this purpose is the power density spectrum:

$$\Phi_{RR}(\omega) = \lim_{T\to\infty} \frac{1}{2T}\,[R_T(j\omega)R_T(-j\omega)] \qquad \text{(f)}$$

where $R_T(j\omega)$ and its conjugate $R_T(-j\omega)$ are the Fourier transforms of the random variable over a period of time from T to $-T$.

A linear stable system of gain $G(j\omega)$ with an input power density spectrum $\Phi_{RR}(\omega)$ will have an output density

$$\begin{aligned}\Phi_{LL}(\omega) &= \lim \frac{1}{2T}[R_T(j\omega)R_T(-j\omega)G(j\omega)G(-j\omega)]\\ &= \Phi_{RR}(\omega)|G(j\omega)|^2 \end{aligned} \qquad \text{(g)}$$

By summing the power density spectrum over the entire range of frequencies, the mean square value of the random variable is obtained:

$$r_{ms} = \frac{1}{2\pi}\int_{-\infty}^{\infty} \Phi_{RR}(\omega)\,d\omega \qquad \text{(h)}$$

It can be further shown by consideration of the superposition integral that the power spectrum function can be obtained from the Fourier transform of the autocorrelation function,

$$\Phi_{RR}(\omega) = \int \phi_{rr}(\tau)e^{-j\omega t}\,dt \qquad \text{(i)}$$

than the noise, while at high frequencies the noise magnitude is greater. This condition can be used to advantage in determining the preliminary design of an involved control system by setting the bandwidth of the system approximately equal to the frequency at which noise and signal are equal. Improvement will result from giving the open-loop system a lead characteristic at low frequencies.

Saturation

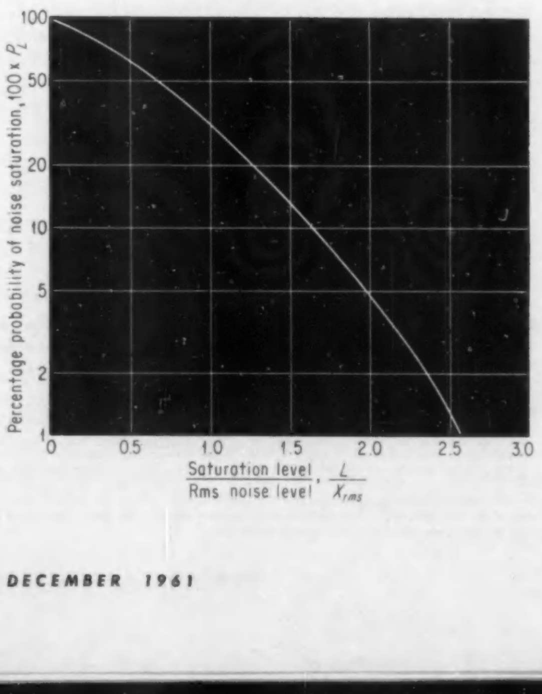
In choosing the parameter values to minimize $\bar{e}^2$, care must be taken to consider the possible saturation effects caused by noise components in the control system. With the noise amplitudes obeying a Gaussian probability distribution it can be expected that there is a certain probability that saturation will occur for certain percentages of the time. If the noise is considered Gaussian, then the probability P_L that the noise will exceed a given magnitude is given by the area under the density curve (see figure and Equation b on page 88) from $-\infty$ to $-L$ and L to ∞. Utilizing the symmetry of the Gaussian curve and making the noise amplitudes and saturation level nondimensional in terms of the rms value of noise, an integral expression for P_L is

$$P_L = \sqrt{\frac{2}{\pi}} \int_{L/X_{rms}}^{\infty} \exp\left[\frac{1}{2}\left(\frac{X}{X_{rms}}\right)^2\right] d\left(\frac{X}{X_{rms}}\right) \quad (10)$$

A plot of this probability as a function of L/X_{rms} is shown in Fig. 2.

Once the rms value of the noise input to a component of a control system is determined by methods previously explained, the probability of saturation can be directly read from this curve. If the ratio of rms noise to saturation level is 2, the component can be expected to be saturated about 5 percent of the time. However, command signals are generally present as well and must be considered in determining the saturation level of the stages involved.

FIG. 2. Percentage probability of saturation as a function of ratio of saturation level to rms noise level.



Extensive research in this field has resulted in extensions and modifications of the basic theory applied to special situations. The optimization of systems and the prediction problem have been considered for the situation when the signal as well as noise is random (Refs. 1 and 7). A procedure for introducing constraints, such as system bandwidth and maximum power, has been presented (Refs. 3, 8, 9, and 10). A graphical technique of analysis to optimize the maximum hit probability density for fire control systems is available in Reference 5. Further generalization of the square-error criterion with an arbitrary weighting function is given in Reference 11. The problem that the system error may only be of interest during a small interval of time, such as when the missile is approaching the target, rather than for all time, is considered in Reference 12. Work also has been done to extend these techniques to sampled data systems (Refs. 13 and 14).

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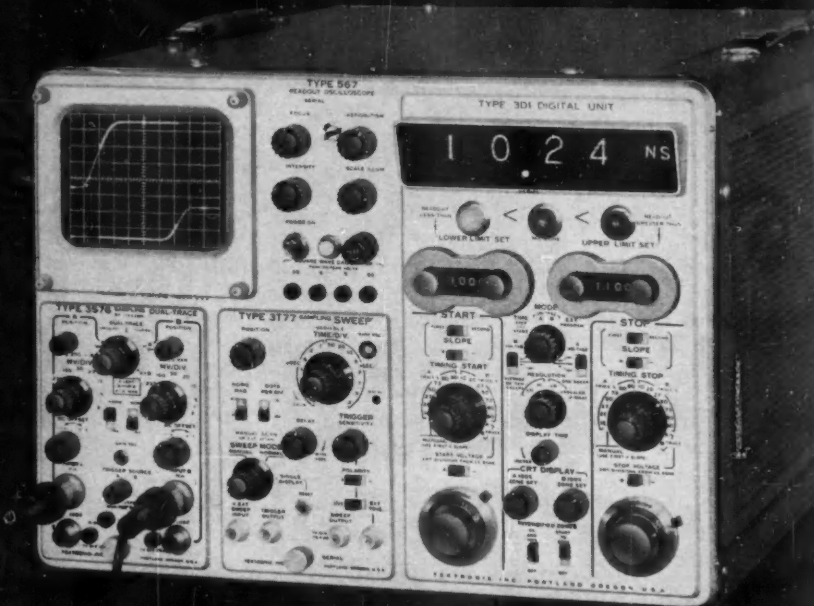

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Simple Equation Links Stabilizing Techniques

M. VAN TOL, N. V. Philips Gloeilampenfabrieken, Netherlands

A simple expression derived from the idealized feedback circuit of Figure 1 explains all the normal compensation methods for securing desired system response. It yields values for phase lead and lag networks, settings for two or three term controllers. The formula is $A = \tau_1/\tau_2$, where A is the loop gain for a 45-deg stability margin and τ_1 and τ_2 are the system's largest two time constants.

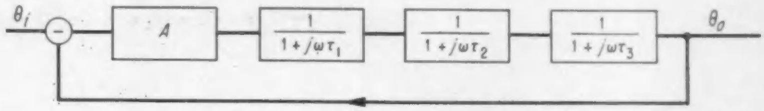


FIG. 1. Closed control loop with proportional controller, uncoupled RC elements.

The upper part of Figure 2 shows the straight-line frequency response approximation for the elements of Figure 1. For each element the phase difference between input and output is exactly 45 deg at the frequency where $\omega\tau$ equals 1. Assuming that the element time constants differ by at least a factor of 5, the over-all phase shift will be approximately -45 deg at $\omega\tau_1$ equals 1, -135 deg at $\omega\tau_2$ equals 1, -225 deg at $\omega\tau_3$ equals 1, etc. The closed-loop dynamic behavior, expressed as a function of θ_i and a process disturbance D, is

$$\theta_o = \frac{AG}{1+AG}\,\theta_i + \frac{1}{1+AG}\,D$$

where

$$G = 1/(1+j\omega\tau_1)\,(1+j\omega\tau_2)\,(1+j\omega\tau_3)\ldots$$

To minimize both offset and the effect of disturbances, A should be as large as possible without introducing instability. Normal practice calls for a 45-deg phase margin—unity loop gain at the frequency where the over-all phase difference is 135 deg. From Figure 2, this is at the second break point where $\omega\tau_2$ equals 1. Because the frequency response between τ_1 and τ_2 has a slope of -1, PR equals RQ. Consequently,

$$\log A - \log 1 = \log \omega_2 - \log \omega_1$$

and

$$A = \omega_2/\omega_1 = \tau_1/\tau_2$$

Applying the basic formula

All practical schemes for improving system stability can be derived from this formula. Here are six methods:

1. The simplest is to increase τ_1, the largest time constant in the process. When this is possible, the loop gain can be raised by the same factor without altering system response.

2. Alternatively, τ_2, the next to largest time constant, can be reduced, but its new value must still be considerably larger than τ_3 for the approximation to remain valid. Reducing τ_2 makes for faster response.

3. A phase lag network with frequency response

$$\frac{Y}{X} = \frac{1+j\omega\tau_b}{1+bj\omega\tau_b}$$

will, in effect, raise τ_1. If τ_b is made equal to τ_1, the factor $1/(1+j\omega\tau_1)$ representing the influence of the largest time constant is replaced by $1/(1+bj\omega\tau_1)$. Now the system has an apparent largest time constant $b\tau_1$, and loop gain can be raised by the factor b.

4. τ_2 can also be reduced effectively by a phase lead network with response

$$\frac{Y}{X} = \frac{1}{c}\,\frac{1+j\omega\tau_c}{1+j\omega\tau_c/c}$$

Here τ_c is made equal to τ_2 so that in the open-loop characteristic τ_2 is replaced by τ_2/c, allowing loop gain to

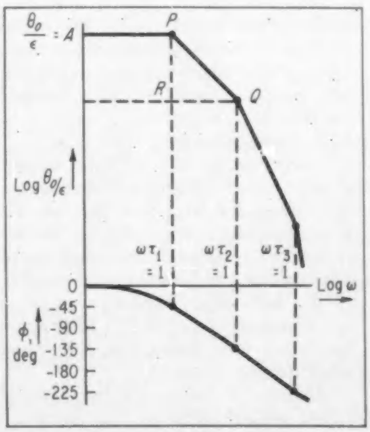


FIG. 2. Open-loop log frequency and phase characteristics of elements shown in Figure 1.

be raised by the factor c. Results are the same as when τ_2 is physically decreased except that the filter introduces a dc attenuation factor $1/c$. The magnitudes of c and b are about 10.

5. In a proportional plus reset controller, deviation ϵ is integrated with respect to time. For sinusoidal signals, the controller response is

$$\frac{Y}{\epsilon} = A\,\frac{1+j\omega\tau_i}{j\omega\tau_i}$$

But in practice, integrators are seldom perfect; dc amplification is not infinite, but has a limiting value B. The actual frequency response is then

$$\frac{Y}{\epsilon} = AB\,\frac{1+j\omega\tau_i}{1+Bj\omega\tau_i}$$

This is the same as for a phase lag network, and when τ_i is made equal to τ_1, τ_1 is replaced virtually by $B\tau_1$. The only difference is that B is generally made larger than b.

6. With a proportional plus rate controller, the theoretical response is

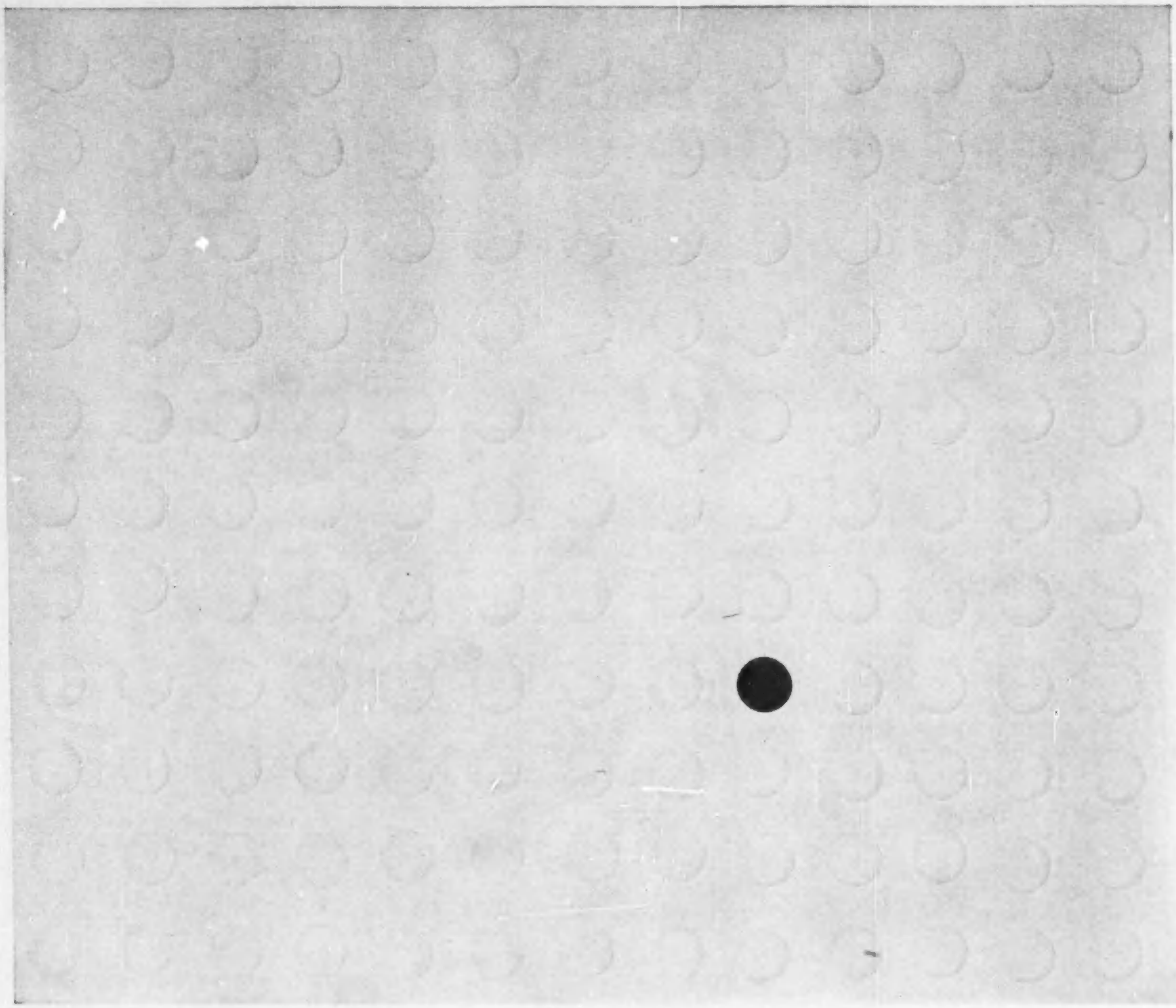
$$\frac{Y}{\epsilon} = A\,(1+j\omega\tau_d)$$

But the upper frequency limitation of practical differentiators makes this

$$\frac{Y}{\epsilon} = A\,\frac{1+j\omega\tau_d}{1+j\omega\tau_d/C}$$

where C is some limit much greater than 1. This function is the same as for a phase lead network, and τ_i should be made equal to τ_2. C can be made considerably larger than c for the passive network case; both C and B have magnitudes in the order of 100.

With a three term controller, the system's largest time constant is increased by reset action, and the second largest time constant is decreased by rate action. The well-known settings for a 45-deg stability margin—reset term equal to the system's τ_1 and rate term equal to τ_2—follow from 5 and 6.



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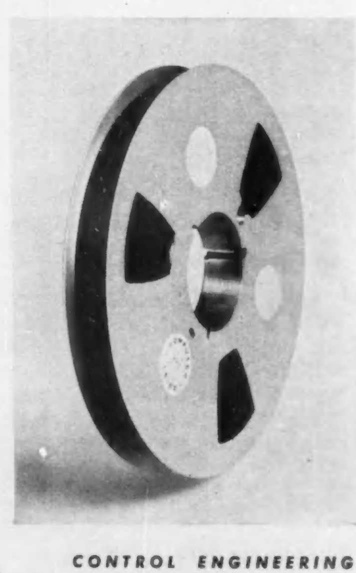

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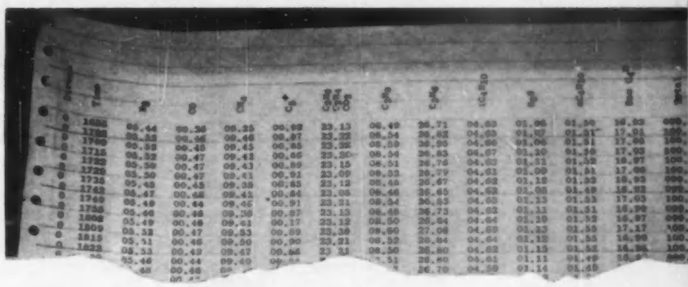
Stream Analysis and Data Reduction in Pilot Plants



Because of their unique role in process operation, pilot plants provide fertile ground for development and try-out of advanced instrumentation and control ideas. On one hand, instrumentation at the pilot plant increases efficiency of obtaining process data, and on the other it leads to improvement in design and control of new plants.

F. W. KARASEK, Research and Development Dept., Phillips Petroleum Co.

Process pilot plants yield information that enhances process and control knowledge. For the control engineer, the goal here is to develop automatic unattended systems that sense, gather, and reduce process measurements to accurate quantitative data.

This goal holds true for pilot plants whose primary study objectives are to provide continuing process information on existing commercial plants. These are usually long term study projects. Here unattended automatic pilot plant control simplifies the operator's task and assures the process engineer that he has accurate data.

The goal also holds true for those pilot plants associated with new processes where information is being developed to commercialize the process. These are usually short term projects. Here, the primary benefit is the development of analytical instruments and control systems during the design stage of new plants, since such an approach at the pilot plant stage can effect economies of design and increased capacities for the new commercial plant.

The general requirements of the instrumentation for the two types of pilot plants are similar, but call for a different approach to application. For example, stream analyzers assigned to new-process pilot plants (short term projects) must be more flexible and versatile than those for routine study of commercial-process pilot plants (long term projects).

Some specific aims of instrumented pilot plants are to: obtain more data in less time, improve data quality, obtain needed data otherwise impractical to determine, and increase productivity of available manpower.

The first step in attaining these benefits is to increase instrumentation for on-stream analyses. Analytical instruments at the pilot plant eliminate the long time lag between obtaining samples and receiving analytical results from a laboratory, and by the elimination of this lag the instrumentation makes practical the characterization of such non-steady-state operations as the detection of process transients and the determination of response times. Once the data measurement problem is solved by installation of stream analyzers, the next step is to devise systems for automatic data reduction. Then the final step is the application of automatic control for unattended pilot plant operation.

Stream analysis for pilot plants

The six most general and significant requirements of analytical instrumentation for pilot plants are:

1. **Use of very small samples**—Most pilot plants operate with exceedingly small flow rates of gases and liquids. Many flows range from 1 to 2 cc per min. Suppose the flow rate of a pilot plant's reflux stream is 1 cc per min and the analyzer requires a 1 cc sample. If the total reflux stream is bypassed into the analyzer the reflux stream would run dry for 1 min to make up the required sample volume. This would constitute a severe and unreasonable disturbance to plant operation. On the other hand

if only 0.1 cc per min is bypassed to the analyzer and 0.9 cc per min maintained as reflux, then it would take 10 min to make up the sample. The disturbance would not be so great, but the sample would represent a 10-min average, not the essentially instantaneous sample needed for timely stream analysis.

2. Versatility of measurement—The life and direction of pilot plants is so different from commercial plants that plans must call for the use of the same analytical instrument in several different places throughout its life to justify its development or purchase. Versatility is also called for because some pilot plants operations become dormant or have their emphasis shifted even in the short interval between instrument purchase and delivery.

3. Wide range of calibration—The product of pilot plants is data, and obtaining this data requires an investigation over wide ranges of conditions. Hence, the same instrument should be capable of being changed with ease to the desired range so that the instrument can readily follow the varying plant conditions.

4. Ability to perform new and unusual measurements—New processes and investigations of previously undetermined parameters require new types of measurements. In this category can be included such common measurements as boiling range, density, and viscosity made under the unique pilot plant restrictions of small sample size and continuous measurement. For catalytic processes, trace analyses are particularly predominant.

5. High accuracy—To make data meaningful, greater measurement accuracy is needed in pilot plants for monitoring and control of associated commercial plants.

6. Continuous process-type design—Such design can assure compatibility of a specific instrument with other plant apparatus, suitability to pilot plant conditions, and can offer the reliability and automatic operation needed for unattended plants.

A case in point

Of the several types of continuous process analytical instrumentation available for petroleum and petrochemical pilot plants, one instrument—the process chromatograph—stands out. Its capabilities match each requirement enumerated above.

1. Sample size—0.05 cc of gas, and 0.005 cc or less of liquid.
2. Versatility—Readily changed from one analytical use to another.
3. Wide calibration range—Can be made linear over wide ranges.
4. Ability to perform new and unusual measurements—The scope of its analytical ability for gases and liquids has only been touched.
5. Accuracy—Capable of a high accuracy and reproducibility.
6. Continuous process-type design—Process chromatographs of several different makes have been operating in plants for many years.

The process chromatographs now available are capable of sampling either gases or liquids and producing analyses of complex mixtures with 10 or more components in minutes rather than hours (Reference). For example, 12 components in the C_2 to C_5 range can be analyzed in 30 sec to 1 min. This ready access to analytical information by individual pilot plants permits modes of operation never possible before. Most analytical problems, difficult because of mixture complexity or trace sensitivity requirements, can be solved to some useful degree by the chromatographic principle.

The versatile chromatograph is able to perform trace measurements, in the ppm range, in situations where a single purpose, specific instrument had to be used previously. An example is the measurement of ppm water in a reactive olefinic stream. An instrument that measures trace water concentrations by the electrolytic (P_2O_5 cell) principle proved unsatisfactory because of rapid polymerization of the olefin on the P_2O_5 element. But by first converting the water to hydrogen over a calcium hydride reactant, the hydrogen produced can be measured with a chromatograph and the reading stoichiometrically related to water content.

Analog data reduction

Information can be rapidly gathered and used immediately when data processing devices, which perform simple calculation, are added to the analytical ability of the chromatograph. A general example illustrates this point. A frequent measurement in pilot plant studies is that of product ratio. In a very elementary conversion process, such as butane isomerization, where

$$n\text{-}C_4H_{10} \xrightleftharpoons{\text{catalyst}} i\text{-}C_4H_{10}$$

the product ratio is

$$\frac{(i\text{-}C_4H_{10})}{(i\text{-}C_4H_{10}) + (n\text{-}C_4H_{10})}$$

This ratio is affected by such parameters as catalyst poisons, feed changes, temperature, and catalyst type.

The ratio determination can be produced continuously by use of a chromatograph feeding into a simple ratio computer. As shown in Figure 1, the functions required of the ratio computer are integration of the chromatographic peaks corresponding to concentrations of $i\text{-}C_4H_{10}$ and $n\text{-}C_4H_{10}$, summing, ratioing, and storage. With complete analyses occurring at about one minute intervals, the computer produces an essentially continuous electrical signal representing product ratio. To study the process under constant ratio conditions merely requires that an appropriate variable (temperature, for instance) be closed-loop controlled by the ratio signal.

Figure 2 illustrates two sets of data produced by this system. The ratio vs catalyst temperature curve is plotted out directly by the ratio computer in a

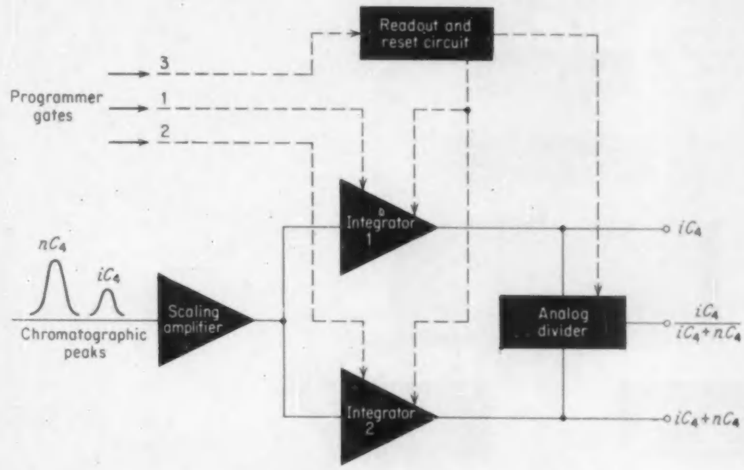


FIG. 1. Ratio computer develops signals to automatically plot curves in Figure 2. First, programmer gates 1 and 2 open, permitting integration of the isobutane peak in both integrators. Next, gate 1 closes, storing the isobutane peak at integrator 1 output. Then, the normal butane peak will only add to integrated value of isobutane already in integrator 2 and the sum is stored at integrator 2 output. Finally, gate 3 is energized to read out the ratio developed by the analog divider, and the entire circuit reset for the next analysis.

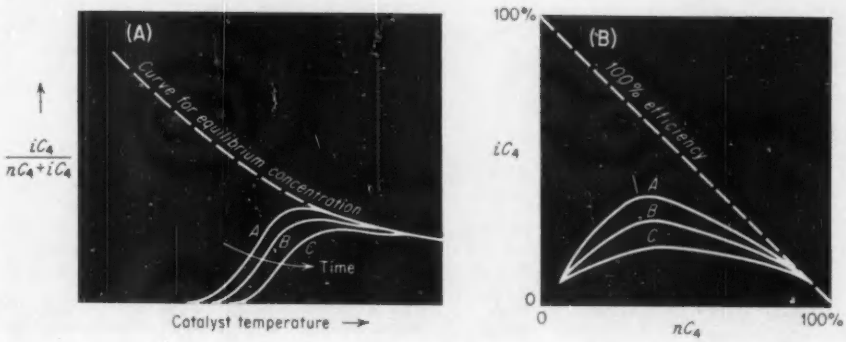


FIG. 2.
Automatic stream analysis and data reduction saves many weeks in obtaining significant process relationships. Here, catalyst temperature increases at fixed rate.

matter of hours whereas conventional methods require weeks. As shown in Figure 2A, time is a parameter of the three different curves. Thus, curve A can represent the yield ratio for a new catalyst, and curves B and C the ratio for the same catalyst but at different stages of aging. On the other hand, for a comparison of three new, different catalysts, the measuring and data reduction system will again plot three curves like A, B, and C.

With a slight change in programmer sequencing, the ratio computer shown in Figure 1 can be modified to produce and hold signals equivalent to iC_4 and nC_4 at the output terminals. Then plots like those shown in Figure 2B can be produced automatically, using an X-Y recorder. Again, the three curves represent either three different runs of the same catalyst or three different catalysts.

Digital data reduction

Perhaps the most important and useful combination of a chromatograph and a data reduction system is one that rapidly produces a total analysis of a complex mixture and presents it in digital form. Because of cost and complexity of using a general purpose digital computer to accomplish this, many pilot plants need a more simplified unit with the single purpose of producing such data. Thus, not only is analytical information immediately available to the operator, but it is in a form useful for further calculations such as to determine material density and viscosity.

A system for presenting such a total analysis in digital form has been developed, Figures 3 and 4. The programmer uses a punched card to control chromatograph functions and signal gates and to select the proper bridge attenuation that compensates for differences in detector response factors. Integration of chromatographic peaks by a voltage-to-frequency converter provides linear response over a wide dynamic range. Each peak integral is stored and a simple ratio computation provides a normalized total analysis. Provision is made to deliver the data either to a typewriter for visual presentation or to a digital computer for further processing.

Pilot plant instrumentation for new processes

The pilot plant provides an ideal workshop for rapid development of unique instrumentation whose

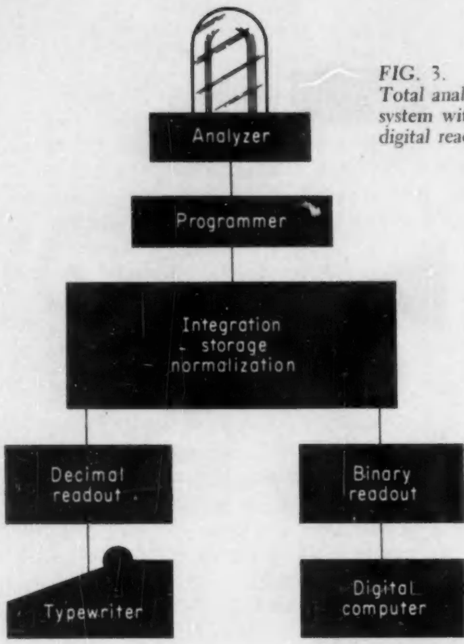
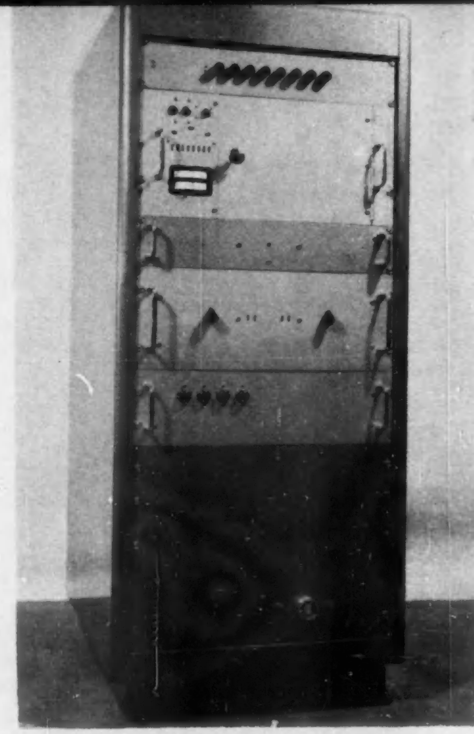


FIG. 3.
Total analysis system with digital readouts.

FIG. 4.
What the total analysis digital system looks like.



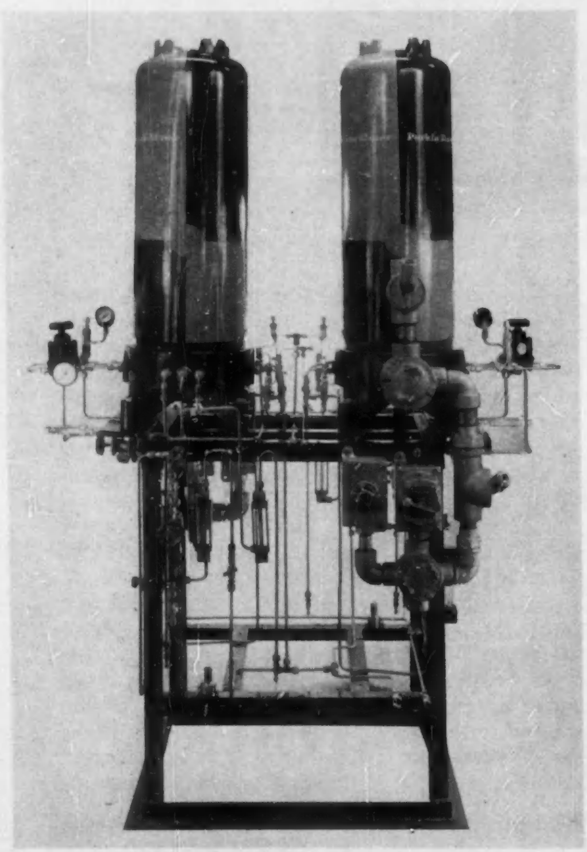


FIG. 5. Control analyzer units and sampling system.

need becomes apparent during the design of a new plant. Once such a measurement and control problem has been clarified the specifications of the anticipated system can be fixed and incorporated in the commercial plant design. However, actual tryout of the system is made at the pilot plant. An instrument company capable of producing the final equipment is brought into the project early. Close liaison during the progress of the control system's development in the pilot plant and in the different stages of equipment manufacture will result in delivery and installation of the specified final system prior to new plant startup.

A special control analyzer system was developed jointly by Phillips Petroleum and Perkin-Elmer in this way, Figure 5. This system samples in the liquid phase for a chromatographic analyzer, integrates the key chromatographic peaks, and presents a continuous 3-15 psi pneumatic output signal proportional to the concentration of a component in the feed stream. Total concentration of impurities are also measured and recorded. A 98 percent service factor is obtained by employing two complete systems in parallel so that one system can be serviced while the other maintains automatic control. An accuracy of ± 0.2 percent is attained. The entire final system had a six weeks' trial run in the pilot plant operation. As a result of this development project, the new plant received a unitized sampling system-analyzer-controller with a tested performance level far superior to that generally available.

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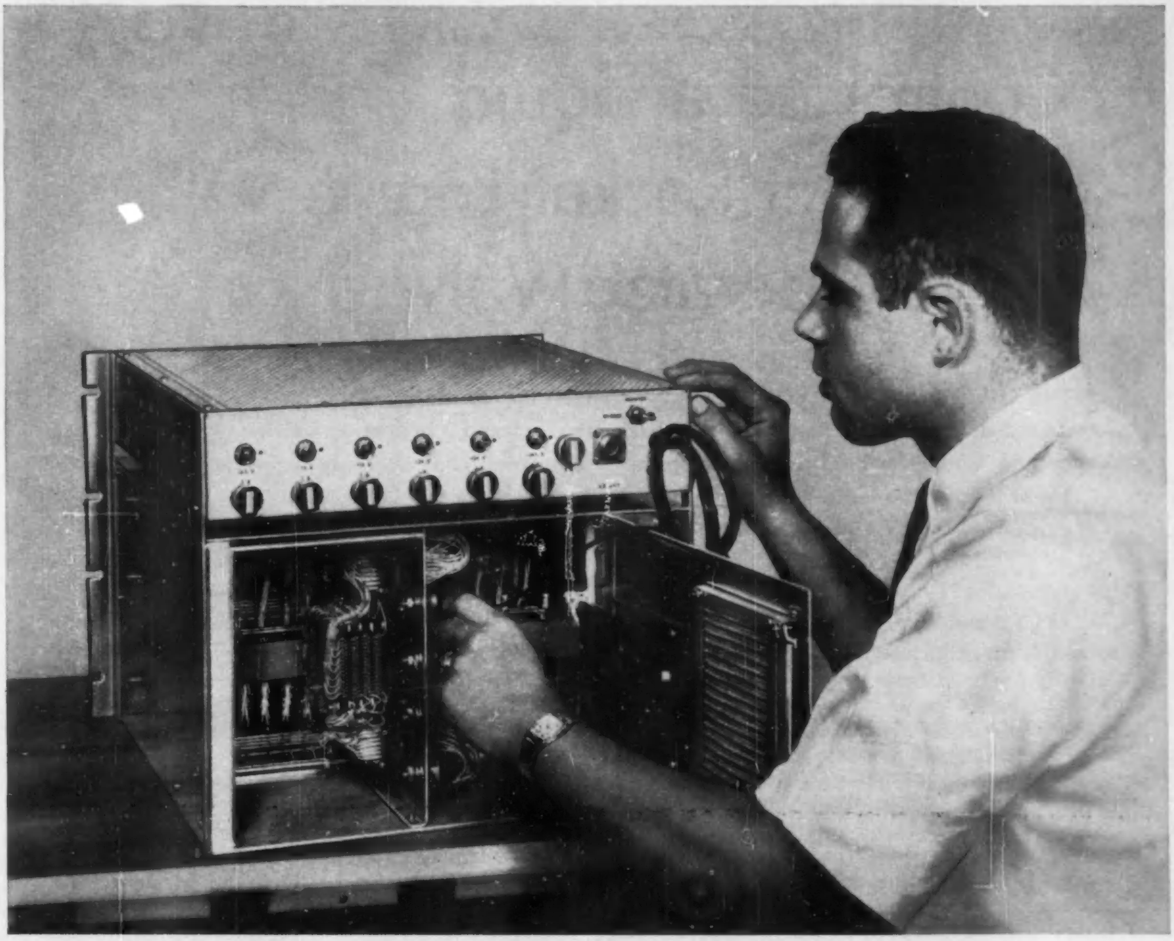

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Controlling a Liquid Propellant Rocket Engine with Servo-Operated Valves

THE GIST: A chamber pressure and mixture-ratio control system increased the safety and speed of testing a regeneratively cooled, hydrogen-fluorine rocket engine and permitted investigation of its general controllability. The system starts the engine, provides stable operation, and limits transient deviations in the oxidant-fuel ratio sufficiently to avoid a stoichiometric mixture.

E. W. OTTO and R. A. FLAGE
National Aeronautics and Space Administration

In a research program to investigate the performance and cooling requirements of a regeneratively cooled, hydrogen-fluorine rocket engine at the Lewis Research Center, a chamber-pressure (P_c) and oxidant-fuel ratio (O/F) control system was developed to:

- increase safety during experiments,
- increase the amount of data that could be obtained in a given amount of running time, and
- investigate the general controllability of the rocket engine and liquid propellant combination.

The control system contributed to the safety of the experiments by incorporating rapid shutoff valves and flow control of each propellant independent of engine operation conditions, and data were obtained at an increased rate because the system provided for running several engine operation conditions (P_c or O/F) consecutively. Although control of *combustion chamber* pressure and oxidant-fuel ratio was used in this program, the technique for control of *thrust* and oxidant-fuel ratio would be similar.

The control system of Figure 1 used with the propellant feed system of Figure 2 has proved capable of starting the hydrogen-fluorine rocket engine,

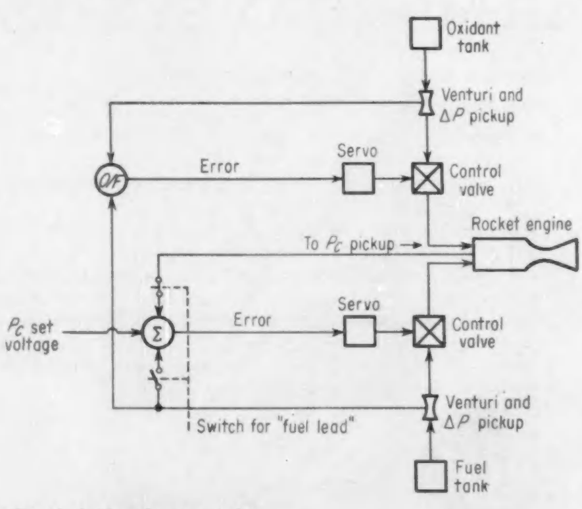

FIG. 1. Oxidant flow is varied to desired O/F ratio, fuel flow to get control chamber pressure, P_c.

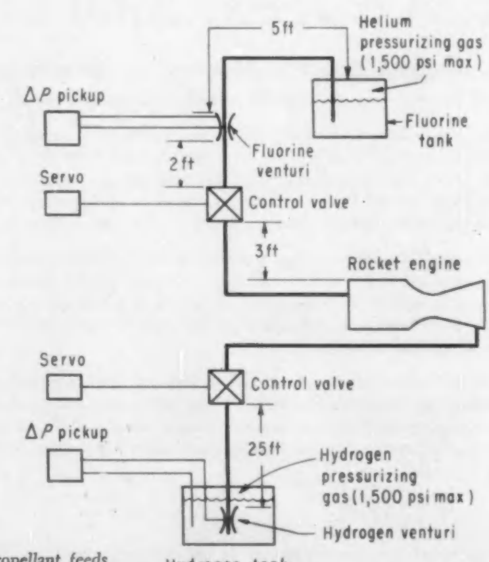

FIG. 2. Each propellant feeds from pressurized tank through venturi and control valve to engine.

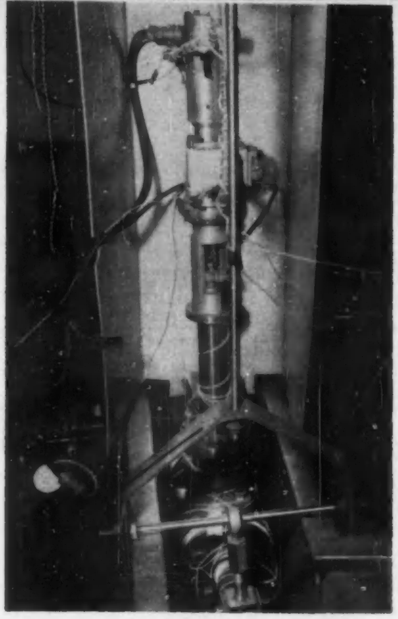

FIG. 3. Fluorine actuator and control valve.

Electrohydraulic servo valve . . .

. . . and how it operates.

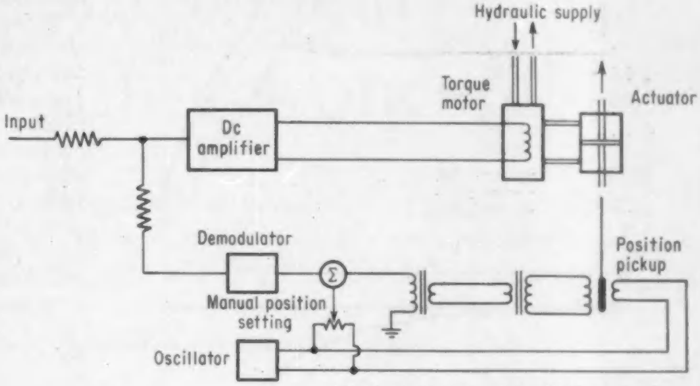

FIG. 4. Position signal is added to signal from manual position pot, demodulated, and compared with input voltage.

providing stable operation to within ±2 percent of the preset values of chamber pressure and oxidant-fuel ratio, and limiting transient deviations in O/F sufficiently to avoid a stoichiometric mixture. In addition, the control system is capable of multipoint stepping of oxidant-fuel ratio and chamber pressure through any range within the rocket engine and instrumentation system capability, and the speed of response of the control valve actuators is more than adequate for safe emergency shutdown.

Control method

Oxidant-fuel ratio is obtained by feeding the 0 to 1-volt fuel and oxidant ΔP signals to opposite ends of a potentiometer and feeding the resulting signal at the wiper arm to the oxidant control valve servomotor. The resulting valve movement varies oxidant flow until zero voltage is obtained at the wiper arm. This method of obtaining O/F control requires that the oxidant voltage be 0 to −1 volts of full-scale ΔP range, and the desired O/F is set by setting the position of the wiper arm.

Control of the chamber pressure is obtained by comparing the 0 to 1-volt P_c signal with a desired voltage and feeding the resulting error voltage to the fuel control valve servomotor. The resulting valve movement varies fuel flow, which in turn varies oxidant flow. This change in propellant flows varies chamber pressure, and the control action continues until zero error voltage is obtained at the input of the fuel control valve servomotor.

It is also possible to obtain O/F control by varying fuel flow and P_c control by varying oxidant flow, but the method described above was chosen because it more easily satisfies certain of the safety requirements. Specifically, it makes certain that there is no oxidant flow unless fuel is actually flowing. It also lends itself to providing the fuel flow lead necessary for purging of the engine and line cooling.

To avoid attack of uncombined fluorine on chamber walls, the engine must be run below the *oxidant-fuel ratio corresponding to a stoichiometric* mixture. With the control method chosen (i.e., control of O/F through oxidant flow and control of P_c through fuel flow), it is necessary to deliberately reduce the speed of response of the fuel control loop below the maximum permissible response speed of the oxidant control loop so that the oxidant flow control can follow the most rapid variations in fuel flow. This technique ensures that transient deviations in O/F never go above stoichiometric.

Servo-operated control valve

The electrohydraulic actuators for the propellant control valves are identical. Each actuator consists of a piston assembly, a Moog electrohydraulic servo valve, and a Schaevitz linear variable differential transformer for position pickup. Figure 3 shows one of the actuators installed in the rocket test cell.

Housings, end plates, and mounting yoke are all made of aluminum. The piston and shaft are made of stainless steel. No special bearings are used because the stainless steel piston and shaft running in aluminum housings and end plates form satisfactory bearing surfaces. Both static and dynamic seals are O-rings, and where high pressures are involved, Teflon backup rings are used.

A second piston and cylinder assembly is gas pressurized to hold the control valve closed during long periods of preparing the propellant system prior to firing. During these periods, this separate valve closing system makes it unnecessary to operate the electrohydraulic servosystem, avoiding the attendant chance of failure of electronic or hydraulic components. This piston is not pressurized when the automatic control system is in operation.

Hydraulic pressure is supplied to both units at 1,500 psi by an electric vane-type pump with a relief

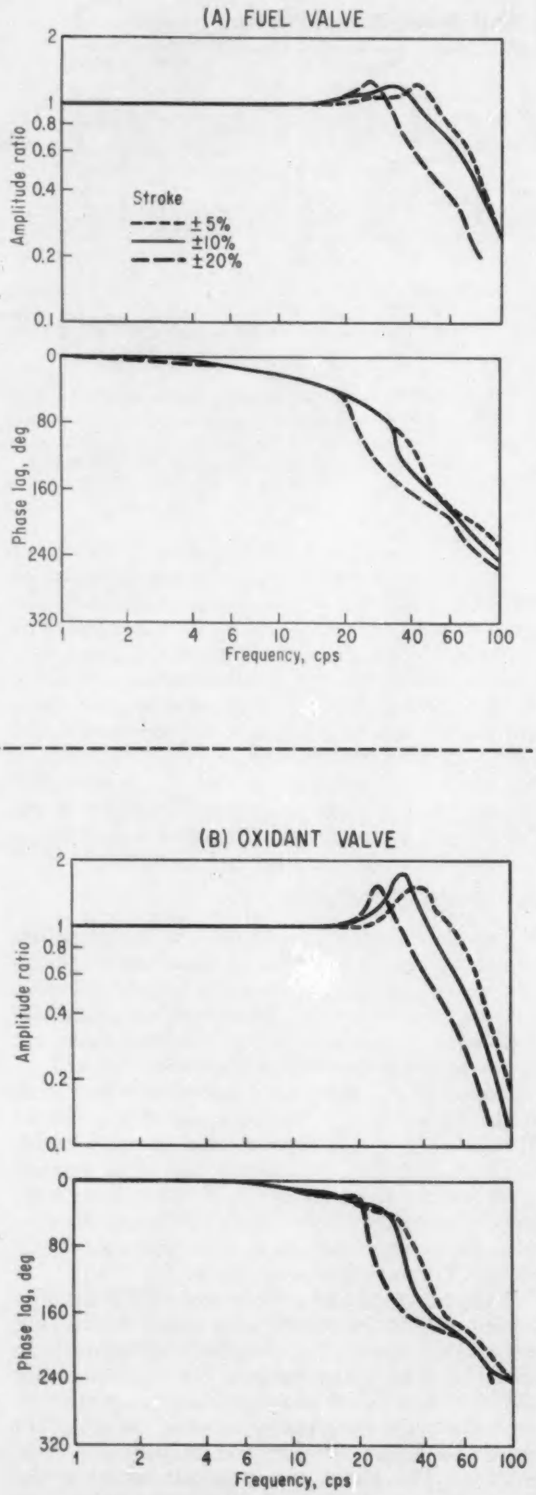

FIG. 5. Results of frequency response tests for inputs corresponding to various percentages of total valve stroke.

valve and accumulator; 10-micron filters are used ahead of each valve actuator.

In the electronic servoamplifier, Figure 4, the actuator position pickup, energized from the carrier oscillator, produces an ac voltage proportional to the displacement from center. The polarity is either in phase or out of phase with the oscillator, depending on the direction from center. The step-down and step-up transformer system enables the position signal to be transmitted at low impedance over long lines without appreciable phase shift. The position signal from the output of the step-up transformer is added to the signal from the manual position potentiometer, and the resulting error signal is demodulated to obtain a dc voltage proportional to position error. The error signal is supplied to the dc amplifier, which produces a differential torque-motor current that, in turn, produces a hydraulic flow to one side of the actuator piston.

The steady state characteristics of this loop are such that there will be a valve position for every setting of the manual-position potentiometer. The valve also can be positioned by introducing a dc voltage at the servoamplifier input. There will be a unique relation of input voltage against valve position for each manual position setting. In the actual tests, the manual position potentiometer was set so that, with zero voltage at the input, the valve was held closed. This satisfied the safety requirement that the valve should return to a closed position with programmed or emergency system cut off. The frequency response of valve position to input voltage is presented in Figure 5.

Performance

The control system performed accurately and rapidly enough to provide good engine data, but the speed of response was limited by the frequency at which an underdamped second or higher order resonance occurred in each control loop. The existence of this resonance necessitated the use of integral control with as small a proportional component as possible (considerably less than one).

The primary source of the resonance was the flow measuring system, composed of a venturi, ΔP pickup, and connecting lines. The underdamped response of the flow measuring system is caused by the inductance of the slug of liquid and the capacitance of the trapped volume of gas in the ΔP pickup and connecting lines. This resonance problem will be encountered in cryogenic systems unless means are found to keep the ΔP pickup and connecting lines either completely full of liquid or completely full of gas.

REFERENCE

CONTROL OF COMBUSTION-CHAMBER PRESSURE AND OXIDANT-FUEL RATIO FOR A REGENERATIVELY COOLED HYDROGEN-FLUORINE ROCKET ENGINE, E. W. Otto and R. A. Flage, NASA-TN-D82, National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio, November 1959.

Fiber Optics Yields A New Scanner Concept

Fiber optic geometry converters make possible electromechanical area scanners that will compete with electron beam scanners in their lower ranges of speed and resolution, while offering simplicity, stability, and long life. Special configurations based on this concept can serve as sensing elements for measurement, control, tracing, tracking, recognition, encoding, decoding, remote observation, and display.

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Gulton Industries, Inc.

Mechanical optical scanners have a number of advantages for industrial use over electron beam scanners and image dissectors. They are simpler and relatively inexpensive, and they have very long life and inherent geometric stability. But most conventional mechanical scanners have the disadvantage that they provide line scanning only. Practical area scanners have been too large or too slow for many applications. The so-called "fiber optic geometry converter" now makes practical a new concept in mechanical scanning that promises to eliminate the size and speed problems while retaining the advantages of conventional designs.

The fiber optic geometry converter is based on the light transmission properties of optical fibers, which are fine strands of optical quality glass that are coated or clad with a glass of lower refractive index. Light rays that enter the end of such a fiber with an angle of incidence less than about 50 deg are reflected repeatedly at the interface between the fiber core and the coating, see Figure 1. Thus trapped within the fiber, they rebound back and forth as they propagate along the fiber and finally leave the opposite end of the fiber at exactly the same angle to the axis that they had at the input. The 100-deg total acceptance angle is wide enough to gather all rays from almost any practical optical lens system. The transmission efficiency of a typical optical fiber decreases from 100 percent at zero length to 60 per cent for a fiber 1½ ft long, and 36 percent for 3 ft.

Optical fibers are made in diameters down to less than 0.001 in. and are quite flexible. Thus they can be gathered together into tight bundles and used to carry a complex image by breaking the image up into small components and transmitting each component independently from one end of the bundle to the other. In such an arrangement, the ends of the fibers must be in exactly the same positions in the image areas at both ends of the bundle or else the picture will be scrambled or distorted. This very possibility permits the design of the fiber optic geometry converter.

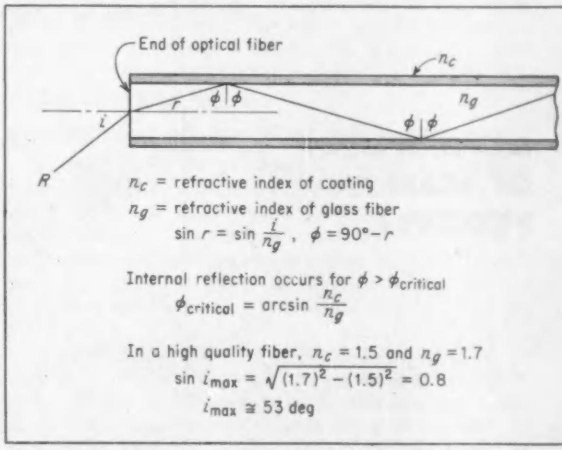


FIG. 1. Light transmission in an optical fiber.

Thus, the individual elements of an input image can be rearranged into any desired sequence at the exit end of the bundle. Hence the term geometry converter. Fiber optic geometry converters that purposely distort an image according to a predetermined pattern are called coherent bundles, just as are bundles that transmit an image without distortion. A bundle of fibers with no specified relationship between input and output fiber ends is a noncoherent bundle. A noncoherent bundle is much easier to make than a coherent one.

Optical fibers can also be tapered, either individually or in bundles, and tapered coherent bundles make excellent image magnifiers.

The fiber optic scanner

Figure 2 shows how Gulton Industries proposes to apply a fiber optic geometry converter to area or line scanning. The scene to be scanned is imaged on an array of fiber ends by an objective lens. The figure shows only a 4 × 3 array of fiber ends in the image plane for simplicity, but

thousands will be used to get much higher image resolution. The output ends of the geometry converter fibers are arranged around the circumference of a circle in line sequence starting at a-1 and proceeding counter-clockwise to c-4. A radial slit disc rotated counter-clockwise will then allow light from each fiber in turn to be focussed on a photo-multiplier by a condensing lens.

Depending on the fiber spacing in the output plane and the width of the scanning slit, the output signal from the photomultiplier will be either an electrical analog describing the light variation along a row of fibers or a series of discrete pulses whose individual amplitudes are a function of the light transmitted by each individual fiber.

Thus, in this scanner the fiber optic geometry converter dissects the input image element by element and arranges it into a convenient form for optical commutation without complex mechanical motion. Because the radial slit scans all of the elements of the image in one revolution, the rotational speeds of common electric motors will commutate complete images at repetition rates up to 60 cps (3,600 rpm).

Optical scanning requirements and conventional scanners

Optical scanning is basically a sampling process that observes each resolvable element of an image or scene in turn. The rate at which the process must be repeated depends on the required continuity of observation. The human eye requires a high repetition rate to eliminate flicker in changing scenes (TV scans 30 complete scenes or frames per second). Considerably lower rates are permissible for scenes that change slowly or not at all, or are not viewed directly by the eye. Some facsimile systems, for example, take up to 20 minutes to print a picture.

Most optical scanning systems are fast-retrace linear scanners (radial in radar and sonar, orthogonal in television and facsimile), but the process

DEVELOPMENT OF SCANNER PRINCIPLE

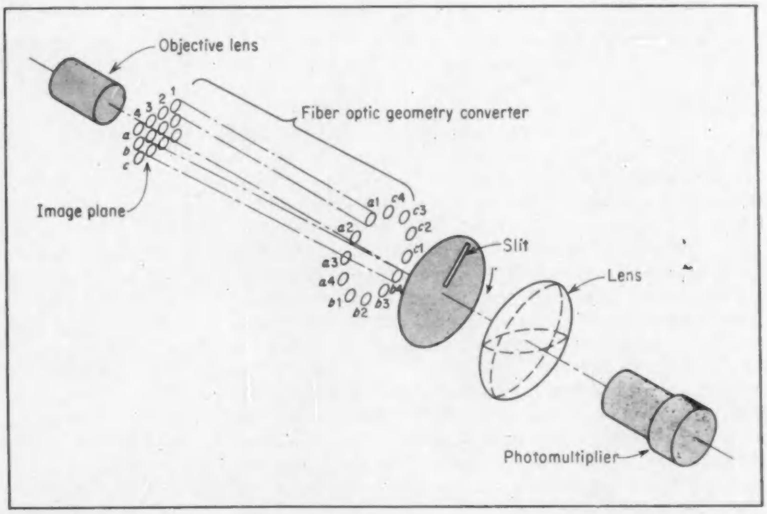


FIG. 2.
Basic elements of the fiber optic scanner.

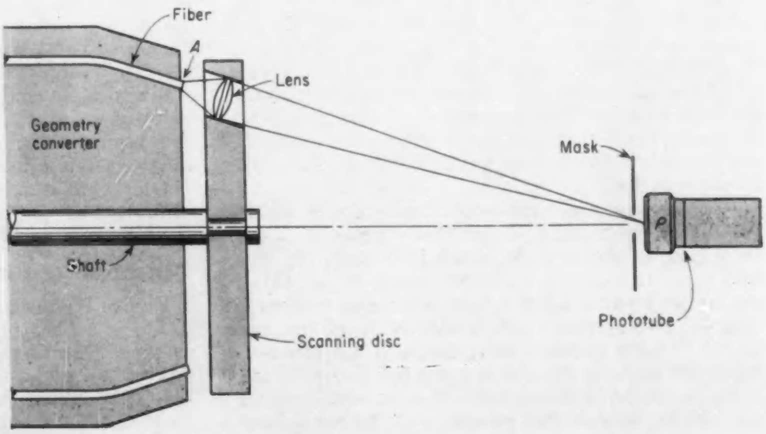


FIG. 3.
Revolving lens in place of radial slit increases light efficiency of scanner 28 times.

is not restricted to these forms. Continuous linear scanning on a to-and-fro basis, spiral scanning, and random scanning systems are also possible, as are point-by-point, or dot scanning processes.

Electron beam scanners

Electron beam scanners focus the scene on a photosensitive layer of some type, and scan this layer in vacuum with an electron beam.

Advantages. The major advantages of electron beam scanners is high speed: frame repetition rates of 200 cps or more are possible. They are also capable of high resolution and high sensitivity. Practically all of them will resolve 250,000 picture elements per frame. Some can resolve up to 4,000,000 elements per frame. Electron beam scanners are sensitive to scene brightness values down to a fraction of a ft-lambert, with some special tubes performing in a limited fashion down to 10^{-6} ft-lamberts.

Disadvantages. All electron beam scanners require external circuits to provide beam deflection fields for scanning, to focus the beam, and to synchronize the scanning waveforms. Practically all of them require careful control of potentials within the tube to achieve stable operation. Accurate scanning geometry is difficult to achieve and even more difficult to maintain.

With the exception of the cathode-ray tube flying-spot scanner, all electron beam scanners have some tendency to non-uniform sensitivity over the scanned area. This non-uniformity changes with time, scanning velocity, and electron gun alignment. It makes stable quantitative measurement of image brightness very difficult.

All electron beam scanners employ a hot cathode for electron emission and, therefore, have limited life. In some types, degradation of the photosensitive area itself is the limiting item.

Image dissectors

The image dissector is a photoemissive camera tube in which an electromagnetically deflected electron image is moved over a fixed aperture. It shares the speed advantage of electron beam scanners. It does not have a hot cathode, but it shares the other disadvantages of electron beam scanners and is considerably less sensitive.

Mechanical scanners

Mechanical scanners move a physical aperture through space to analyze the optical image area.

Advantages. All scanning and synchronizing information can be derived from the single synchronous motor which drives the scanner. They are simple, stable, need little or no adjustment, and have long life. These features result in low first cost and low operational cost.

Disadvantages. Most mechanical scanners will scan only in a line. The other component of scanning motion must be provided by moving the object plane itself at right angles to the direction of line scanning. This involves the construction of very accurate, complex mechanical assemblies.

The spiral slit scanner and multiple spiral slit scanner are common varieties of line scanners. They can be made with excellent geometric accuracy and high resolution. Convenient sizes can resolve 2,000 picture elements per line. Practical line scan periods are of the same order of magnitude as the period for one revolution of common synchronous motors. Higher rates require gearing, and only small gear ratios are practical. If area scanning is required without moving the object plane, a frame synchronous moving mirror can deflect the optical path. For a system requiring even as few as 60 lines, the frame period would be 1 sec with a 3,600 rpm motor.

The Nipkow disc, one of the oldest mechanical scanners, is simply a system of spirally arranged apertures at equally spaced angles on an opaque disc rotated at frame speed. A Nipkow disc will scan a whole frame of information in one rotation and it shares the advantages of mechanical scanners. But it has several disadvantages relative to the fiber optic scanner: the large diameter of a practical Nipkow disc, the large size of the objective lens, the relative geometric inaccuracy, and the great difficulty of fabricating an aperture disc with even moderate accuracy.

Advantages of the fiber optic scanner

Besides the inherent high speed of a complete frame scan per revolution, the disc carrying the radial slit can be reasonably small in the fiber optic scanner. For example, a medium resolution 20,000 element area scanner could have at its output end 1-mil diam fibers arranged on 1 mil centers around a circle of 6.37 in. diam (20 in. circumference).

A practical version of the scanner shown in principle in Figure 2 will have a revolving lens in place of the radial slit, see Figure 3. The small revolving lens is placed to image the end of each fiber in turn on the photosensitive area. To collect all available light, the lens need only have a diameter sufficient to accept the full emerging light cone from one fiber at a time. Because practical input objective lenses limit the cone half-angle to about 25 deg, a revolving lens of f/1.0 will be sufficient. The quality of the image is not significant, so an f/1.0 single-element lens of very small diameter (8 mm or less) can be used. Such lenses are commonly available.

To ensure that only the image of one fiber end reaches the photosensitive surface at a time, the photosensitive surface must be appropriately masked. The images of the fiber ends will be spaced apart by a distance equal to the fiber spacing multiplied by the magnification of the lens.

If the lens transmission factor is 70 percent, the calculated improvement in light utilization for a typical system is conservatively estimated to be at least 28 to 1 over the simple slit. This improvement will permit the use of fiber optic scanners in many applications without any auxiliary lighting, extending its potential usefulness.

The fiber optic scanner has a number of characteristics which can be significant in industrial and military applications:

- No adjustments except optical focus.
- No scanning, synchronizing, or pickup control

TWO PRACTICAL APPLICATIONS OF FIBER OPTIC SCANNER

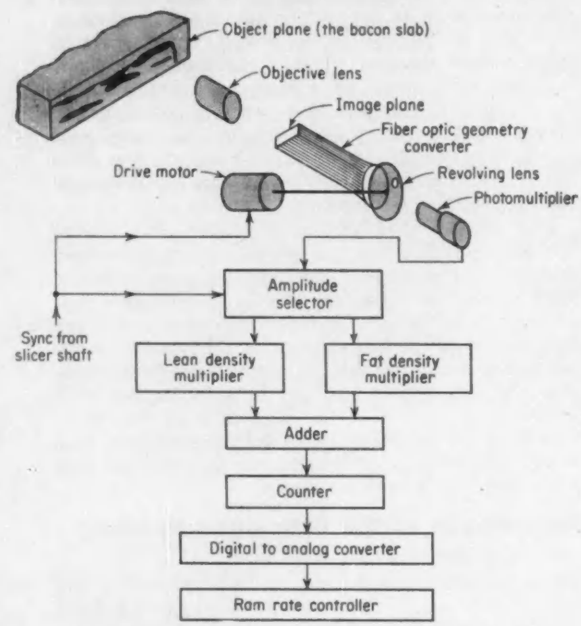


FIG. 4. High speed automatic bacon slicer control.

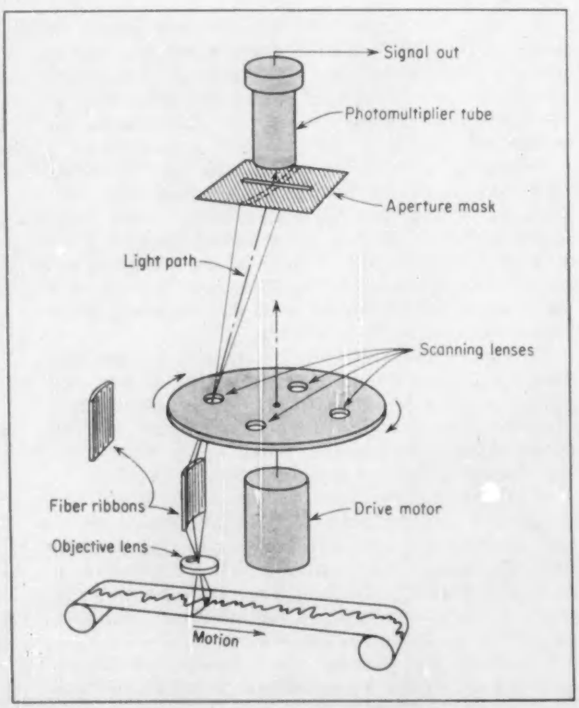


FIG. 5. Scanner for frequency analysis of analog strip chart recording.

circuits to add cost and potential trouble.

- Geometric accuracy can be built in.
- Stable—precision is not prone to variation.
- Long life—limited primarily by motor bearing life. (Multiplier phototubes, having no hot cathode, are extremely long life devices when conservatively applied.)
- Much smaller than Nipkow disc or other mechanical scanners.
- Adaptable to digital processing—availability of pulse-analog output when fibers are separated in the output format permits convenient generation of a synchronizing pulse for control of analog-to-digital conversion circuits.
- Uniform—eliminates almost all sources of non-uniform sensitivity and background shading.
- Versatile—rectangular format of input array in Figure 2 could just as easily be a line, a circle or any other geometric shape, pattern, contour, or character.

Figures 4 and 5 show two variations of the revolving lens fiber optic scanner for practical engineering applications. The first, in Figure 4, is a control system for weighing by optical analog.

Automatic high speed bacon slicing systems must provide means for accurate control of the ram which pushes the bacon slab into the slicer knife. Existing systems "make weight" or count slices in order to arrive at proper package weight, but none provide slice-by-slice control. Figure 4 shows a system using a fiber optic revolving lens area scanner with the output end fibers spaced by the fiber diameter to provide a pulse output. This system analyzes the image at the end of the bacon slab then computes the end area and the lean-to-fat ratio. The final result is an analog control voltage corrected for each slice which has accuracy sufficient to produce constant package weights with a constant number of slices. The advantages of the fiber optic scanner in this application are uniformity of sensitivity over the scanned area and long adjustment-free life.

Figure 5 shows an arrangement of the fiber optic scanner to read analog strip chart recordings for automatic analysis. The system uses two interchangeable fiber ribbon converters with their input ends designed for exact correspondence with the coordinate system on curvilinear and rectilinear recording papers. The output ends of the fiber optic converter would be an arc of a circle of convenient size for rotary lens scanning, say 6 in. diameter. Four lenses permit four scans per revolution, or 240 scans per sec for a 3,600 rpm drive motor. Allowing 3 samples per cycle of the highest frequency in the recording, this system will permit analysis of recordings of frequencies up to 80 cps. By running the paper at speeds faster than during recording, time can be saved in the analysis. For example, the same system can be run at 10 times recording speed if the highest recorded frequency is less than 8 cps. The signal processing circuits will provide a pulse width modulated analog of the original recorded signal.

There is a substantial need for scanners in applications requiring quantitative analysis of image areas, particularly in the control field.

Punched Paper Tape Equipment for Medium, Intermediate, and Large Computers

This article compares the significant features and characteristics of punched paper tape input and output devices available as standard equipment with 33 computers in the medium, intermediate, and large size groups. Small computers will be compared in later articles.

Prepared by the staff of
CRESAP, McCORMICK and PAGET

Punched paper tape is a widely used medium for computer input, either in addition to or in place of punched cards.

Punched paper tape has been used for many years as an input and output medium for telegraphic equipment. More recently, it has been used to record information as a by-product of document preparation or checking. Thus, the operation of a typewriter, adding machine, bookkeeping machine, or cash register, to cite a few examples, can create a punched tape record of the data processed, see Figure 1. Combining document preparation with the creation of a machinable medium can eliminate a separate keypunching operation and hence reduce the costs of preparing data for entry into a computer system.

In punched paper tape, the information is recorded as holes punched in rows across the tape. Generally, each row represents one alphabetic character or numeric digit. The maximum number of holes that can be punched across the tape is referred to as the number of "channels" on the tape.

Five-channel tape is normally used in telegraphic systems to record alphabetic and numeric characters. However, a special code must be punched into the tape before each series of characters or digits to indicate whether they are alphabetic or numeric, because five-channel tape permits only 32 different code patterns. To overcome this limitation, six-channel tape is used in some automatic typewriters and in the data transmission systems used by various stock exchanges. The major advantage of six-channel tape over five-channel tape is that 64 combinations of punches are possible in each row, and thus a greater variety of characters and symbols can be recorded.

Seven-channel tape is used on some calculating typewriters and communication systems. Six channels are used to record data, and the seventh permits the validity of the punches in the tape to be checked through a technique called "parity" checking. Parity is automatically established at the time the data are punched into the tape, and provides that all rows shall have either odd or even numbers of holes.

In a system that operates on the basis of "even" parity, a row in which information was recorded in an odd number of holes automatically has a hole added to the parity channel to make the total number of holes in the row even. A row with an even number of holes does not have a hole added to the parity channel. When this even-parity tape is read by a second device, a parity check made by counting the holes in each row identifies any row with an odd number of holes and thus flags the error. This check does not preclude the possibility that data originally could have been punched into the tape incorrectly.

Eight-channel tape includes the parity checking feature of seven-channel tape and the eighth channel provides control over tape processing devices.

Punched paper tape has certain advantages over punched cards as a medium of input to an electronic computer. The most important is that punched paper tape records are not limited in length and can be as long or as short as desired. With punched cards, on the other hand, the entire card must be read even if only one or two columns are needed to record the data, and extra cards must be used if the data takes up more than 80 or 90 columns. Also, punched tape can sometimes be produced more quickly and less expensively than punched cards. Both the tapes and the tape-produc-

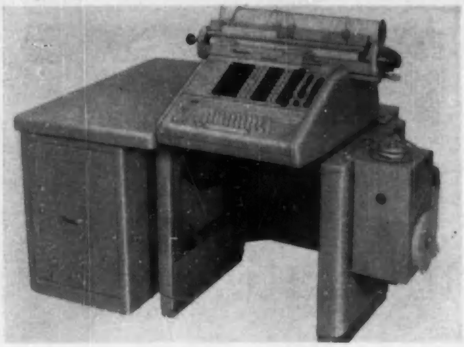


FIG. 1. Burroughs Sensimatic bookkeeping machine produces punched tape record of all transactions as by-product of posting operation.

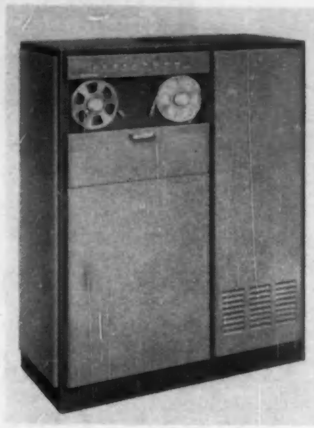


FIG. 2. Model 360 paper tape reader used with National Cash Register Co.'s NCR 304 computer.

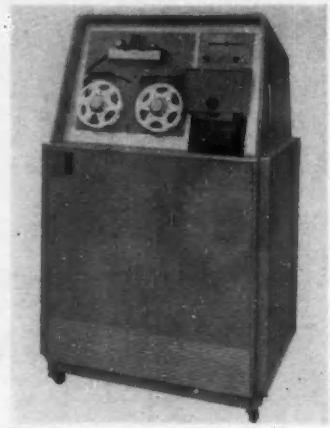


FIG. 3. General Electric 225 computer uses this Model 651-1 paper tape reader and punch.

ing equipments require less space than punched cards and card-producing equipments.

But punched paper tape also has disadvantages as a computer input medium. Once data are punched into paper tape, it is difficult to correct errors. While certain correction procedures permit data punched into the tape to be ignored automatically, such an approach is not equivalent to the ability to delete the data completely before they enter the system. Also, after data have been recorded in punched paper tape, they cannot be manipulated; consequently, data are often hand sorted before being punched into the tape. To ensure accurate sequence, data read into a computer from the tape must often be sorted internally by the computer before further processing can begin.

Paper tape input devices may be faster or slower than punched cards, depending on the operation being performed. For example, a card reader with a rated speed of 800 cards per min could read cards with 80 columns at a rate of 1,067 characters per sec, cards with 40 columns at 533 characters per sec, and cards with 20 columns at 267 characters per sec. A fast paper tape reader can read 1,000 characters per sec. Thus, a choice between the two mediums is more complex than only a comparison of rated speeds.

Paper tape input and output devices generally consist of three elements: a feed reel, a reading or writing station, and a take-up reel, Figures 2 and 3. As the tape moves from one reel to the other, it passes either a reading or a punching device.

Paper tape readers and punches that serve as input and output devices for computers are presented in separate Equipment Comparison Tables. These tables review speed and capacity, the functions performed, and the checking provided.

The devices are compared under each characteristic on the basis of features regularly offered for sale by the manufacturer as standard or optional equipment. The tables do not include custom-built features. As with card readers and punches, the features of paper tape input and output devices do not, of themselves, indicate which computer is the best machine for a given application. Only an evaluation of total computer systems can reveal this. However, comparison of paper tape input and output equipment can reveal factors significant to individual prospective computer users.

Criteria for paper tape equipment

This section defines the criteria by which paper tape input and output devices are compared in Equipment Comparison Tables 7 through 12. The tables have two main divisions: *performance data*—which lists numeric quantities or speeds given by manufacturer's specifications or calculated from specifications; and *capabilities*—which lists other characteristics of the equipment.

Performance data

The speed with which data can be read from or punched into paper tape and the capacity of the paper tape input and output devices are the primary performance criteria considered in comparing these equipments.

• SPEED of paper tape reading and punching is affected by the rated speed of the reader or punch and the time-sharing capability of the computer. **Rated reading or punching speed** is the number of

NOTES FOR TABLES 7 THROUGH 12

a. Higher speed when reading free strips (not reels) of tape.
b. Any input-output device.
c. If no other input except card readers and magnetic tape.
d. If no other output except card punches, magnetic tapes, and printers.
e. Card readers, paper tape readers, and magnetic tape groups.
f. Card punches, paper punches, and printers.
g. Also compares punch set-up with central processor.

Computer name codes: B—Burroughs; **CDC**—Control Data; **G**—Bendix; **GE**—General Electric; **H**—Minneapolis Honeywell; **IBM**—International Business Machines; **NCR**—National Cash Register; **Philco**—Philco; **RCA**—Radio Corp. of America; **U, UFC, USS**—Remington Rand Univac.

Table 7 PAPER TAPE INPUT DEVICES (Medium Size Computers)

COMPUTER	B 200	B 205	CDC 160 A	GE 225	H 400	IBM 650	IBM 1401	NCR 304	NCR 315	RCA 301	Philco 2400	UFC	USS 80 or 90	USS II
DEVICE MODEL NO.	...	409	350	G 651	409	046	1011	360	472-1	321	...	4970	...	...
PERFORMANCE														
● SPEED	NONE												NONE	NONE
Rated reading speed (characters per sec)		540	350	250 or 1000(a)	1000	20	500	1800	1000	100	1000	240		
Time-sharing ability (max percent)		0	99.9	99.1 or 97.2(a)	98.0	98.0	99.9	0	90.0	99.0	99.9	99.9		
● CAPACITY														
Max no. of units		1	4	1	3(c)	3	1	1	1	1	64(b)	10(b)		
Number of channels		6	5,6,7,8	5,6,7,8	5,6,7,8	5 or 8	5,6,7,8	5,6,7,8	5,6,7,8	5,6,7	5,6,7,8	5,6,7,8		
Spool capacity (ft)		100	500	800	500	300	1025	900	1000	1000	700	1000		
CAPABILITIES														
● FUNCTION														
Automatic rewind		NO	NO	NO	YES	NO	YES	NO	NO	YES	YES	YES		
● CHECKING														
Parity		NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES		
Dual reading		NO	NO	NO	NO	YES	NO	YES	NO	NO	NO	YES		

Table 8 PAPER TAPE OUTPUT DEVICES (Medium Size Computers)

COMPUTER	B 200	B 205	CDC 160 A	GE 225	H 400	IBM 650	IBM 1401	NCR 304	NCR 315	RCA 301	Philco 2400	UFC	USS 80 or 90	USS II
DEVICE MODEL NO.	...	409	BRPE 11	G 651	410	...	...	370	472-1	321	...	4970	...	..
PERFORMANCE														
● SPEED	NONE					NONE	NONE						NONE	NONE
Rated punching speed (characters per sec)		60	110	110	110			120	120	100	100	60		
Time-sharing ability (max percent)		0	99.9	99.6	99.8			0	39.0	99.9	99.9	99.9		
● CAPACITY														
Max no. of units		1	4	1	2(d)			1	1	1	64(b)	10(b)		
Number of channels		6	5,6,7,8	5,6,7,8	5,6,7,8			5,6,7,8	5,6,7,8	5 or 7	5,6,7,8	5,6,7		
Spool capacity (ft)		100	3500	800	800			900	900	1000	1000	100		
CAPABILITIES														
● FUNCTION														
Automatic rewind		NO	NO	NO	YES			NO	NO	YES	NO	YES		
● CHECKING														
Parity		YES	NO	YES	NO			YES	YES	YES	YES	YES		

Table 9 PAPER TAPE INPUT DEVICES (Intermediate Size Computers)

COMPUTER	G 20	B 220	B 5000	GE 210	H 800	IBM 1410	IBM 7070	RCA 501	U II	U III	U 490
DEVICE MODEL NO.	PT 10	440	...	...	809	1011	...	512	...	...	...
PERFORMANCE											
● SPEED			NONE				NONE		NONE	NONE	NONE
Rated reading speed (characters per sec)	500	1000		200	1000	500		1000			
Time-sharing ability (max percent)	99.9	0		99.4	99.9	99.9		99.9			
● CAPACITY											
Max no. of units	1444(b)	10		1	8(e)	1		1			
Number of channels	5,6,7,8	7		7	5,6,7,8	5 or 8		7			
Spool capacity (ft)	500	600		800	500	300		1000			
CAPABILITY											
● FUNCTION											
Automatic rewind	YES	NO		NO	YES	YES		YES			
● CHECKING											
Parity	YES	YES		YES	YES	YES		YES			
Dual reading	NO	NO		NO	NO	NO		NO			

Table 10 PAPER TAPE OUTPUT DEVICES (Intermediate Size Computers)

COMPUTER	G 20	B 220	B 5000	GE 210	H 800	IBM 1410	IBM 7070	RCA 501		U II	U III	U 490
DEVICE MODEL NO.	PT 10	470	...	4WH 210A	810	...	...	512	513	...	...	...
PERFORMANCE												
● SPEED			NONE			NONE	NONE			NONE	NONE	NONE
Rated punching speed (characters per sec)	100	60		110	110			100	300			
Time-sharing ability (max percent)	99.9	0		99.6	99.9			99.9	99.9			
● CAPABILITY												
Max no. of units	1444(b)	10		1	8(f)			1	1			
Number of channels	5,6,7,8	7		7	5,6,7,8			5or 7	5 or 7			
Spool capacity (ft)	500	600		800	800			1000	1000			
CAPABILITIES												
● FUNCTION												
Automatic rewind	YES	NO		NO	YES			YES	YES			
● CHECKING												
Parity	YES	YES		YES	YES(g)			YES	YES			

characters of data which theoretically can be read from a tape or punched into a tape from the computer each second.

Time sharing ability indicates the maximum percentage of time available to the computer for the simultaneous performance of other operations while the tape reading or punching operation is in progress. The higher the percentage of time available, the greater the amount of computing, for example, which can be performed during the reading or punching operation.

• CAPACITY of paper tape readers and punches may be measured in at least three ways.

Maximum number of units indicates the maximum number of paper tape input and output units which can be connected into a computer system. Some computers can increase over-all tape reading or punching speed by alternately using several paper tape readers or punches. This increase in speed can be achieved only if speed is not limited by the number or complexity of other operations which must occur between each tape reading or tape punching.

Number of channels indicates the number of channels the device can be made to read or punch. Five-, six-, seven- and eight-channel tapes each have their uses. No determination can be made of which number of channels is best without con-

Table 11 PAPER TAPE INPUT DEVICES (Large Size Computers)

COMPUTER	CDC 1604	IBM 704	IBM 705 III	IBM 7080	IBM 7090	Philco 2000	RCA 601	U 1107
DEVICE MODEL NO.	350	...	...	...	...	241	621	...
PERFORMANCE								
• SPEED		NONE	NONE	NONE	NONE			
Rated reading speed (characters per sec)	350					1000	1000	400
Time-sharing ability (max percent)	99.9					99.9	95.0	99.9
• CAPACITY								
Max no. of units	4					448(b)	15	31(b)
Number of channels	7					5,6,7,8	7	5,6,7,8
Spool capacity (ft)	500					700	1000	500
CAPABILITIES								
• FUNCTION								
Automatic rewind	NO					YES	YES	YES
• CHECKING								
Parity	NO					YES	YES	YES
Dual reading	NO					NO	NO	YES

Table 12 PAPER TAPE OUTPUT DEVICES (Large Size Computers)

COMPUTER	CDC 1604	IBM 704	IBM 705 III	IBM 7080	IBM 7090	Philco 2000	RCA 601		U 1107
DEVICE MODEL NO.	BRPE 11	...	...	...	...	241	512	513	...
PERFORMANCE									
• SPEED		NONE	NONE	NONE	NONE				
Rated punching speed (characters per sec)	110					60	100	300	110
Time-sharing ability (max percent)	99.9					99.9	95.0	95.0	99.9
• CAPACITY									
Max no. of units	4					448(b)	15	15	31(b)
Number of channels	5,6,7,8					5,6,7,8	5,6,7,8	5 or 7	5,6,7,8
Spool capacity (ft)	3500					1000	1000	1000	1000
CAPABILITIES									
• FUNCTION									
Automatic rewind	NO					NO	YES	YES	YES
• CHECKING									
Parity	NO					YES	YES	YES	YES

sidering the source of the tape and how it is to be used.

Spool capacity measures the number of feet of paper tape that can be contained on a reel, and thus indicates the amount of data that can be stored on each reel of tape. More data on each tape can possibly reduce the number of tapes required for a given job.

Capabilities

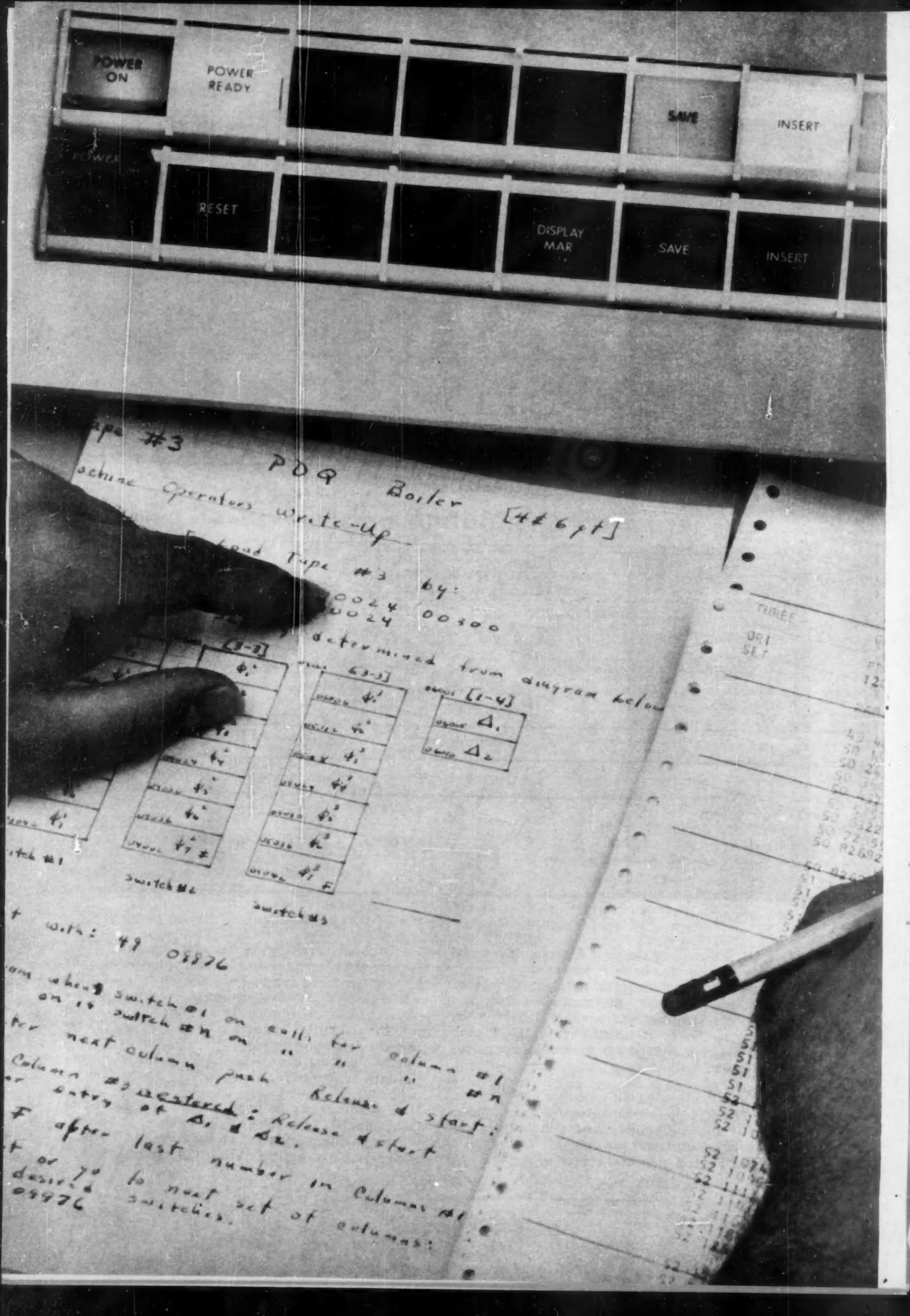
• FUNCTIONS of paper tape readers and punches necessarily include reading and punching; some might include automatic rewind.

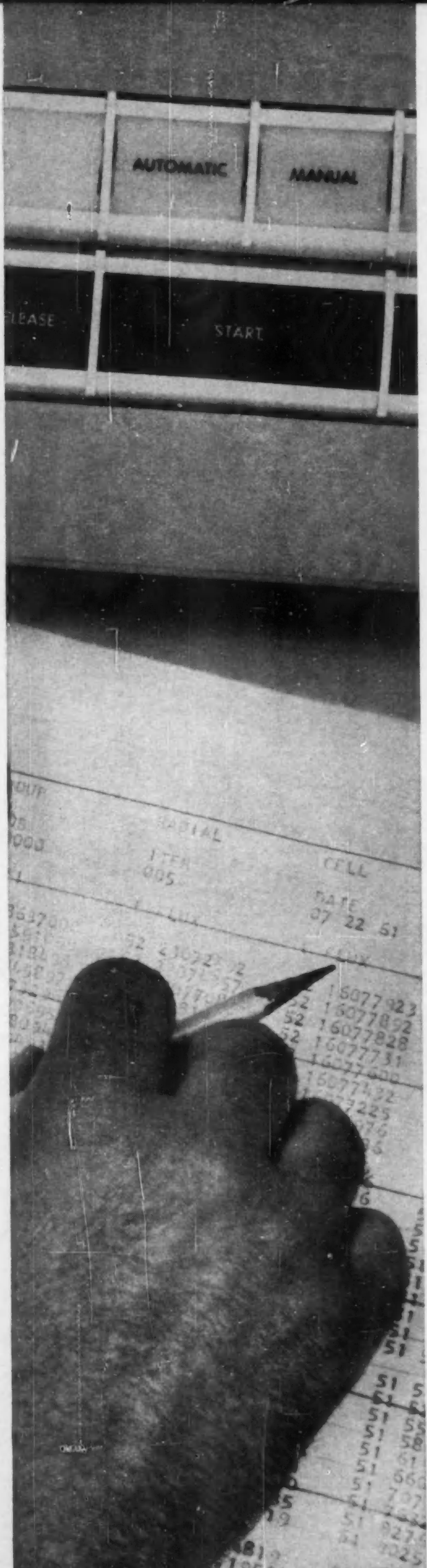
Automatic rewind permits a reel of tape to be mechanically rewound to the starting point. This feature speeds processing by reducing the amount of time required for manual rewinding.

• CHECKING features ensure the accuracy of the data which is being read from punched paper tape into the computer, and may consist of parity checking and dual reading.

Parity checking counts the holes punched across the tape to determine that "parity", as previously defined, exists.

Dual reading may be used in checking data read from punched tape. The reader reads each column twice and compares the two readings. Any difference signals an error or stops the computer.


POWER ON
POWER READY
SAVE
INSERT
RESET
DISPLAY MAR
SAVE
INSERT
PDQ Boiler [4+6pt]



Cost of one-dimensional criticality computations drops from an average of \$75.00 to \$7.50 per problem

Faster computing, less travel time are the reasons why General Nuclear Engineering Corporation has realized such cost savings since it installed an IBM 1620 Data Processing System at its Dunedin, Florida plant.

Since its main computing facilities are not located at Dunedin, General Nuclear has found that the new 1620 eliminates much of the travel time and expense involved in taking problems to off-site computers. In addition, the 1620 performs the simpler criticality computations 10 times faster than the computer previously used at one of General Nuclear's off-site data processing centers.

General Nuclear uses its new 1620 for other problems, too...heat transfer calculations, various transient codes, mathematical routines for the physics and engineering departments, multi-group calculations, and many other jobs you might expect only a much more expensive computer to be able to handle.

This isn't all. General Nuclear uses the 1620 to do statistical analyses and variance calculations on input data for programs run on off-site large-scale IBM computers.

For information on this highly versatile, low-cost data processing system, which rents for as little as \$1600 a month, contact your local IBM Representative.

Easy to program. FORTRAN, IBM's scientific computer language is available for the 1620. General Nuclear scientists use a special scientific interpretive program—FIDO—written by the Manager of their Computing Section.

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DATA PROCESSING

CIRCLE 111 ON READER SERVICE CARD

Looking for a solution to your

BRPE Tape Punch

Perforates 5, 6, 7 or 8 level tape at 100 char/sec. Synchronous unit, with parallel-wire input. For business machine readout, or, with deserializer, for data reception over DATA-PHONE or other high speed communication channels.

CX Tape Reader

Reads fully perforated or chadless tape—5, 6, 7 or 8 level codes—at 100 char/sec. For use as computer input device, or, with serializer, for transmission over DATA-PHONE or other high speed communication channels.

LARP Tape Punch

Produces 5, 6, 7 or 8 level tape at 20 char/sec. Parallel input. May be used for cross-office relaying, data collection, or providing by-product tapes from business machines. Companion input tape reader available (LX).

CIRCLE 113 ON READER SERVICE CARD

Direct Reading Flow Rate Meter:
1-Percent Accurate at Low Rates

J. R. Musham
B. G. Lewis
English Electric Aviation Ltd.

Specification testing of servovalves for aerospace applications calls for direct readout of hydraulic flow rates as small as 0.1 cu in. per sec to accuracies under 1 percent. The only available direct reading technique with the required accuracy–multipiston positive displacement metering–extended down no more than 0.5 cu in. per sec, required calibration, and had a low flow range ratio.

A new specially developed single-cylinder linear stroke meter gives instantaneous direct flow rate readings and is unaffected by temperature, viscosity, and specific gravity errors in the liquid. The single flow transmitter covers a 1,000:1 flow rate range from the 0.05 cu in. per sec minimum with accuracy better than 1 percent.

The 6-in. diam cylinder has a chromium plated liner as an interference fit to maintain true bore throughout its 12-in. length. An aluminum piston with two sealing rings at each end is inserted in the cylinder. Oil entering through one end of the cylinder moves the piston and two rectilinear pots coupled through a connecting rod, Figure 1. The output voltage from one pot wiper feeds an RC differentiator whose output is proportional to the rate of flow of oil into the cylinder. Range may be changed by switching different valued capacitors into the differentiator.

The other pot output voltage measures piston position and operates a pair of transistor switches, one for each end of piston travel. These switches operate relays that energize solenoids in the changeover valve to reverse piston travel. Additional outputs from the transistor switches are available for triggering counters so that the average flow rate over known periods can be measured. To get the necessary accuracy, both pots are fed from a stabilized power supply whose output is kept constant to four significant figures by comparison with a known standard battery.

To avoid pressure transients during changeover of the piston travel, the ¾-in. pilot operated changeover valve bypasses the system during changeover. Another safeguard against transients is viscous damping on the valve spool due to small exhaust and inlet orifices on the pilot valve. A relief valve bypasses the system at 100 psi if the piston fails to reverse.

The indicating meter is fitted with a knife edge pointer and mounted horizontally to eliminate unbalanced forces on the movement but still contributes most of the error–up to 0.5 percent. Cylinder area change due to temperature variations causes 0.05 percent error; leakage flow at minimum flow rate is less than 100 cu microin. per sec; and ambient temperature changes between 15 and 35 deg C add 0.2 percent error.

Figure 2 shows how the flowmeter is applied to obtain complete servovalve flow hysteresis plots. The position pot closes the loop via a servo amplifier and the cylinder; under these conditions the servovalve seeks balanced actuator pressures. A ramp voltage fed into the amplifier drives the system, and a hysteresis curve showing flow rate versus servovalve differential current is produced on an x-y plotter.

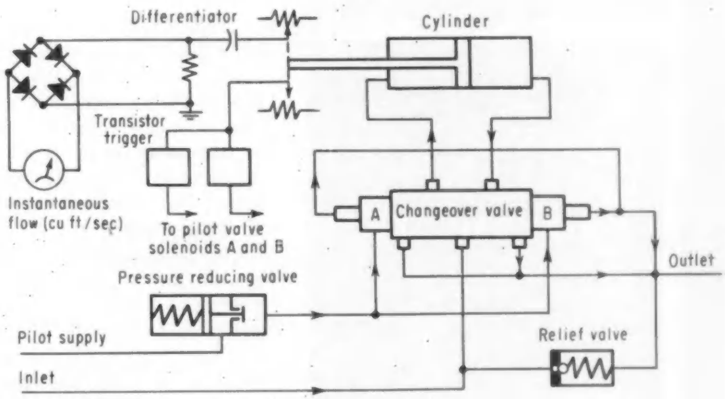
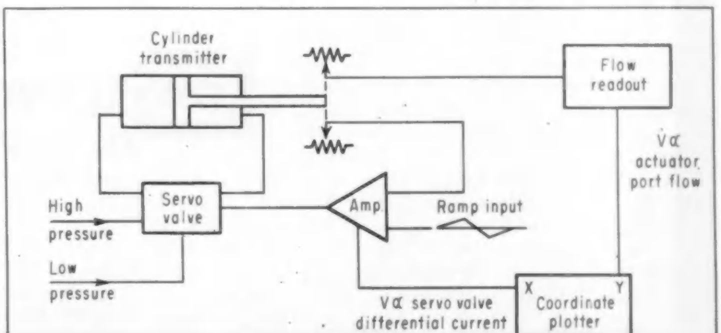


FIG. 1. One pot feeds flow rate differentiator; the other signals end of piston travel.

FIG. 2. Servovalve flow hysteresis loops are plotted automatically.



1 Microsecond

MEMORY MODULES*

*STANDARDIZED

Now available from Daystrom as standard units, these 1 μsec modularized core memories permit manufacturers of digital machines to eliminate expensive component development. The modules offer design flexibility never before available to computer engineers. Full read-write cycle time for the modules is 1 μsec or less, and access time is typically 0.5 μsec. The standard memory has a capacity of 1024 words, 50 bits to the word, and can be expanded in multiples of this capacity up to 4096 words and 200 bits per word. Components are stacked to give high package density. Only two different voltages . . . +20V and −20V . . . are required, and the full driving current is only 360ma. All solid-state and highly reliable, the standardized modules reflect Daystrom Military Electronics Division's extensive experience with MIL memories and circuitry such as the NORC and 465L systems. Send for technical data.

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Analog Computer Checks Autopilots Fast

WARREN J. RUSH
United Air Lines

Conventionally, the roll, pitch, and yaw circuits of an autopilot must be tested one at a time, and a complete test takes as long as 8 hours. Malfunctions in one or more circuits often call for an expensive test flight. But with a new maintenance tool—a special analog computer developed by United Air Lines—an autopilot can be checked dynamically, each circuit in relation to the others, in 30 min.

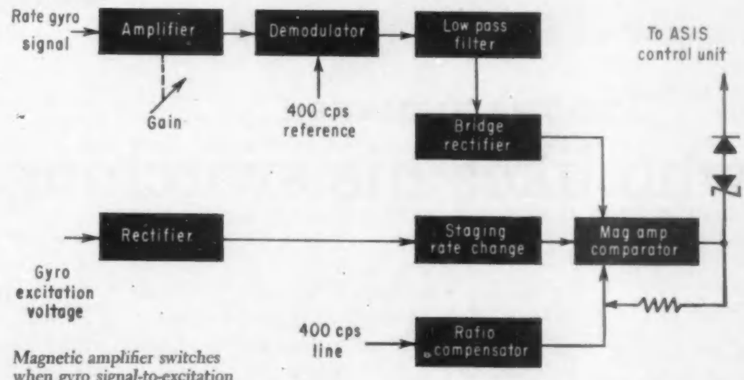
At present, United is using the computer to check autopilots for DC-8's. Voltages representing angular displacements of the aircraft control surfaces are fed into the computer from two sets of potentiometers—one set for approach conditions and the other for conditions of cruise. The computer has 23 dc operational amplifiers (12 for summing and 11 as integrators) patched to simulate the dynamics of the aircraft. Thus, their outputs are analogous to the angular accelerations, rates, and displacements about the roll, pitch, and yaw axes of an aircraft in flight. Scaling is such that machine time equals real time, and 2 vdc equals 1 deg.

The dc outputs from the computer are modified to meet the input requirements of the autopilot: 400-cps suppressed carrier gyro signals (three), accelerometer signals (five), magnetic and radio heading signals, and stabilization computer inputs (three); dc radio displacement signals for glide slope and localizer; and a 28-vdc bank limit switch signal. A six-channel Brush recorder charts the simulated roll, pitch, and yaw attitudes plus the simulated turn and bank indicator ball. The fifth and sixth channels are used to record aircraft position relative to runway heading and glide slope beam in a simulated ILS approach.

United plans to adapt the computer to test the Boeing 720 and Caravelle autopilots as well as other aircraft systems.

Mag Amp Monitors Mercury-Atlas Gyros

R. D. GADBOIS
T. F. HEINSHEIMER
J. W. SCHAELCHLIN
General Dynamics/Astronautics



Magnetic amplifier switches when gyro signal-to-excitation ratio exceeds preset value.

The Atlas has an impressive record, but there have also been failures—some of which have resulted in sudden destruction of the missile. Experience has shown that certain subsystems can be monitored to predict catastrophic failure, but the time between malfunction and explosion is too short for a human decision to abort. In the Mercury-Atlas flights, ASIS (Abort Sensing and Implementation System) watches 13 critical parameters and generates an abort command if any of them deviate beyond preset limits.

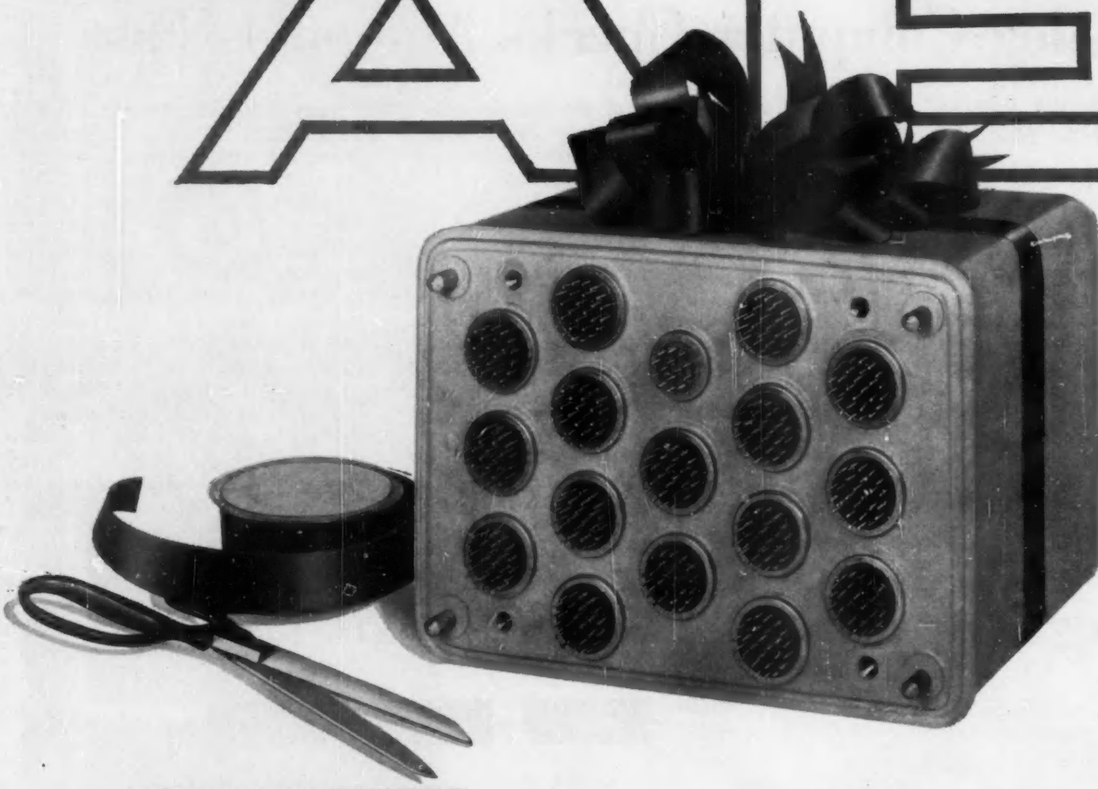
To gage performance of the flight control system, ASIS monitors the outputs of two sets of three rate gyros each that detect rotation about the pitch, yaw, and roll axes. Each gyro has an over-rate detector, see figure, whose output is zero as long as the gyro output is within safe limits. If the gyro output becomes excessive, indicating excessive missile rotation rate, the output of the detector switches to a 7-volt abort signal.

The detector's threshold is established by adjusting the gain of an amplifier acting on the rate gyro signal. Amplifier output goes to a phase sensitive demodulator that removes the 400-cps modulation. Next a low pass filter attenuates high frequency transients that occur during certain phases of flight. After full wave rectification, the signal is fed into one of the control windings of a magnetic amplifier. Another control winding is fed by the gyro excitation voltage, and the third by a ratio compensator. The mag amp measures the ratio of the gyro signal to the excitation voltage. By measuring this ratio, rather than the absolute value of the gyro signal, line voltage variations are canceled out.

The staging rate change circuit in the excitation voltage line changes the amount of rate signal required to switch the mag amp. This is to compensate for changes in the missile's dynamic characteristics when the booster engines are jettisoned. The ratio compensator winding is used to position the mag amp input-output curves so that when both signal and excitation are zero, the mag amp is turned on. Positive feedback decreases the mag amp's response time and prevents it from acting like an analog device. The zener diode in the output line blocks any null voltage that the mag amp may produce when it is off.

Six critical missile pressures—fuel injection pressures of the three engines, lox tank pressure, differential pressure across the main bulkhead, and sustainer hydraulic pressure—are monitored by pairs of pressure switches wired in parallel. The six pairs are wired in series to connect 35 vac, to

AE



TO THE ENGINEER

who likes his switching gift-wrapped

If you want your control functions prewired, hermetically sealed in a neat package, tested out, and as ready as instant coffee, you're listening to the right people.

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a transformer primary when all pressures are normal. The output from the transformer secondary is filtered and fed through zener diodes to mag amp NOT gates. If the pressure chain is broken, the gates turn on. Because of the diodes, low line voltage has the same effect, guarding against failure in the electrical system.

The six over-rate detectors and the two pressure monitoring NOT gates are connected to a pair of NOR gates designed to stay on as long as all inputs are effectively zero. A voltage from any of the eight inputs turns both NORs off, and the escape mechanism recognizes this signal as the abort command. The drop-out of NOR gate output voltage also de-energizes the engine cutoff relays in the control unit. If more than 30 sec have passed since lift-off, the engine cut off capability of ASIS has been armed by the autopilot, and a 28 vdc signal is sent to the engine control system, shutting down the engines. If the malfunction is detected prior to lift-off, the control unit will not send a lift-off enable signal, release will not occur, and the engines will shut down.

Servoed Antenna Tracks Radio "Pill"

BERTIL JACOBSON
Karolinska Institutet, Sweden

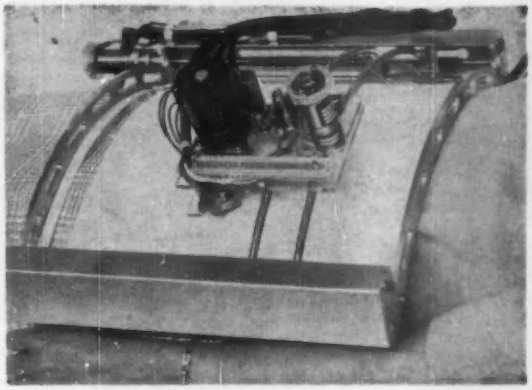


FIG. 1. Revolving antenna and pen follow movements of endoradiosonde.

Endoradiosondes can be placed in a body cavity to remain there during a whole experiment, or they can be swallowed and pass freely through the alimentary canal. Knowing the position of a freely moving endoradiosonde is important, e.g., for interpretation of intraluminal pressure variation.

Sonde position can be found by observing the field strength pattern with an omnidirectional antenna: the point of maximum field strength is the shortest distance from the sonde. But each patient must be investigated continuously for several hours, and making an accurate plot of the sonde's movements becomes a tedious task. Also, it is not possible to get accurate correlations between the movements and the pressure variations.

The servo system described here tracks endoradiosonde movements automatically. It includes an antenna servo, Figure 1; a rack with endoradiosonde receiver, servo amplifiers, and power supply; and a pen recorder. A map of the sonde's movements is drawn by a second pen on a piece of paper supported by a curved plexiglass plate resting on the abdomen. The pen is attached to an antenna carriage that is forced to track the sonde by right-left and cranio-caudal servos.

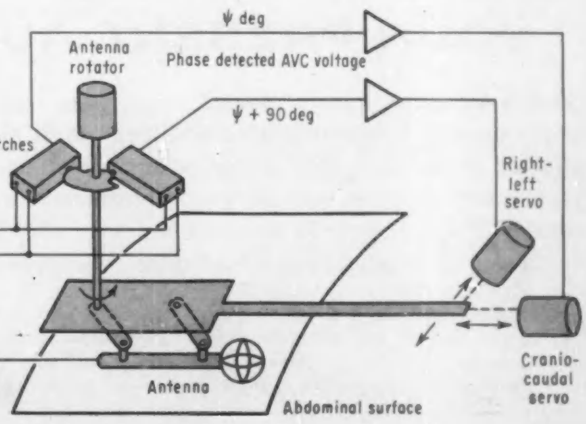
A third motor revolves the omnidirectional antenna at 60 rpm in a circle parallel to the abdominal surface. The signal strength picked up by the antenna is a function of the distance to the endoradiosonde, and the antenna carriage seeks a position where the signal strength stays constant. This occurs when the axis of revolution passes through or near the sonde.

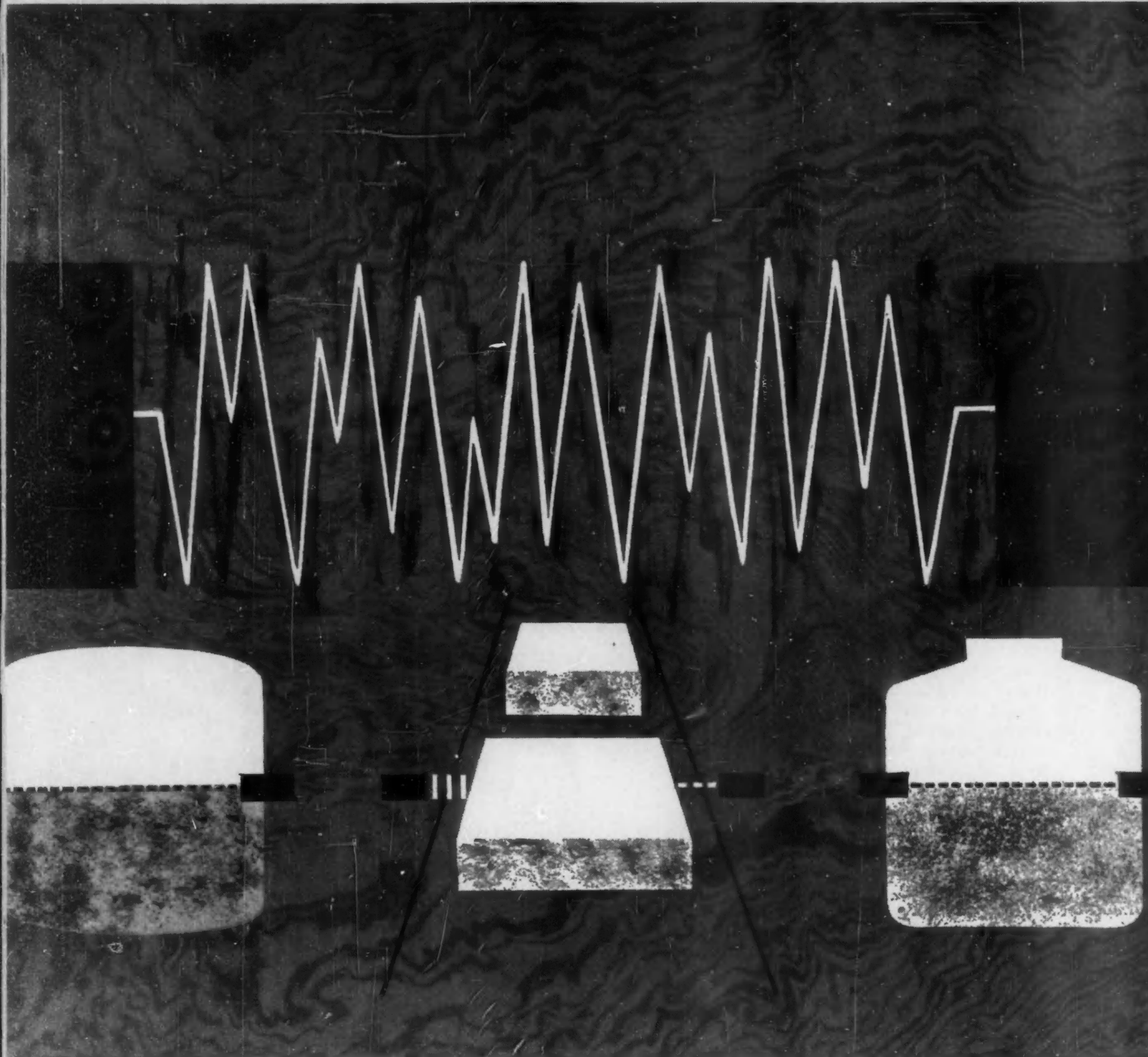
In Figure 2 the antenna is shown coupled to a special endoradiosonde receiver. The receiver's AVC voltage is a function of the signal picked up by the antenna, and any deviation of the antenna from the equilibrium position results in an AVC voltage variation equal in frequency to the antenna rotation rate. Such variations are detected by two microswitches actuated by a cam on the antenna shaft. The switches deliver two phase detected voltages—one proportional to position unbalance in the right-left direction and one to unbalance in the cranio-caudal direction—to control the servos.

The equipment has one systematic error. The field strength pattern from an endoradiosonde has a dipole configuration; when the axes of symmetry of this dipole field do not pass through the center of antenna rotation, the antenna seeks a position where its rotation axis does not pass exactly through the sonde. However, with the present system this error is less than 1 cm. Also, it is difficult to record exactly how far the sonde is below the abdominal surface, but the dc level of the AVC voltage gives a rough measure, limited in accuracy by rf absorption in the body tissues.

This project was supported by research grant A2338 from the National Institute of Arthritis and Metabolic Diseases, U.S. Public Health Service.

FIG. 2. Cam-actuated switches control carriage servos.

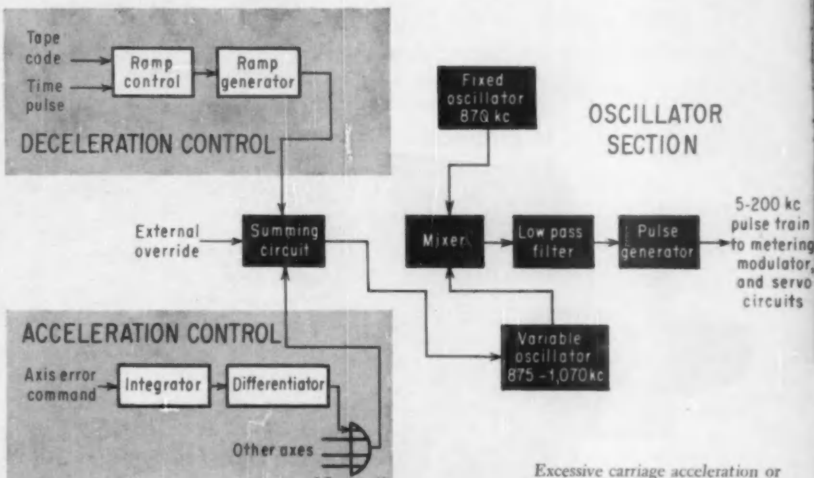





SONAC

Automatic Feedrate Override for N/C Machine Tools

JAMES K. LIVINGSTONE
RICHARD P. BLOSS
Thompson Ramo Wooldridge, Inc.



Excessive carriage acceleration or stop signal on tape depresses feedrate oscillator frequency.

Numerically controlled machine tools can develop excessive acceleration and deceleration forces when commands are given as step functions. Traditionally, this limitation has been circumvented by either reducing the maximum velocity of the system to that attainable in one step or using many steps of velocity to allow the machine tool to operate within its safe limits.

But a new internal feedrate override (IFRO) eliminates the need for "stair step" programming without changing the contouring capabilities of the control system. It modifies the programmed feedrates where necessary to be compatible with the tool's acceleration characteristics, reduces programming time and tape length, and increases productivity. The limitation of deceleration forces allows important reduction of overshoot.

IFRO operates with the TRW Director Control System (DCS). Input to the DCS is a paper tape punched with five-digit groups that specify a straight line synthesis of the desired contour. Each group denotes the number of 1/10,000's of an inch of motion required for a given axis. This 8-4-2-1 binary decimal information is converted into a 5-2-1-1 code and read into the Director's buffer storage, then transferred in parallel to active storage.

Digestion of the data in active storage is a two-part operation: first, feedrate data from the tape meters certain pulses from a train generated by a feedrate oscillator. Each 100,000 pulses in the rate controlled train establishes a cycle, and the axis movement data specifies how many pulses in each cycle are to be fed to each axis command line.

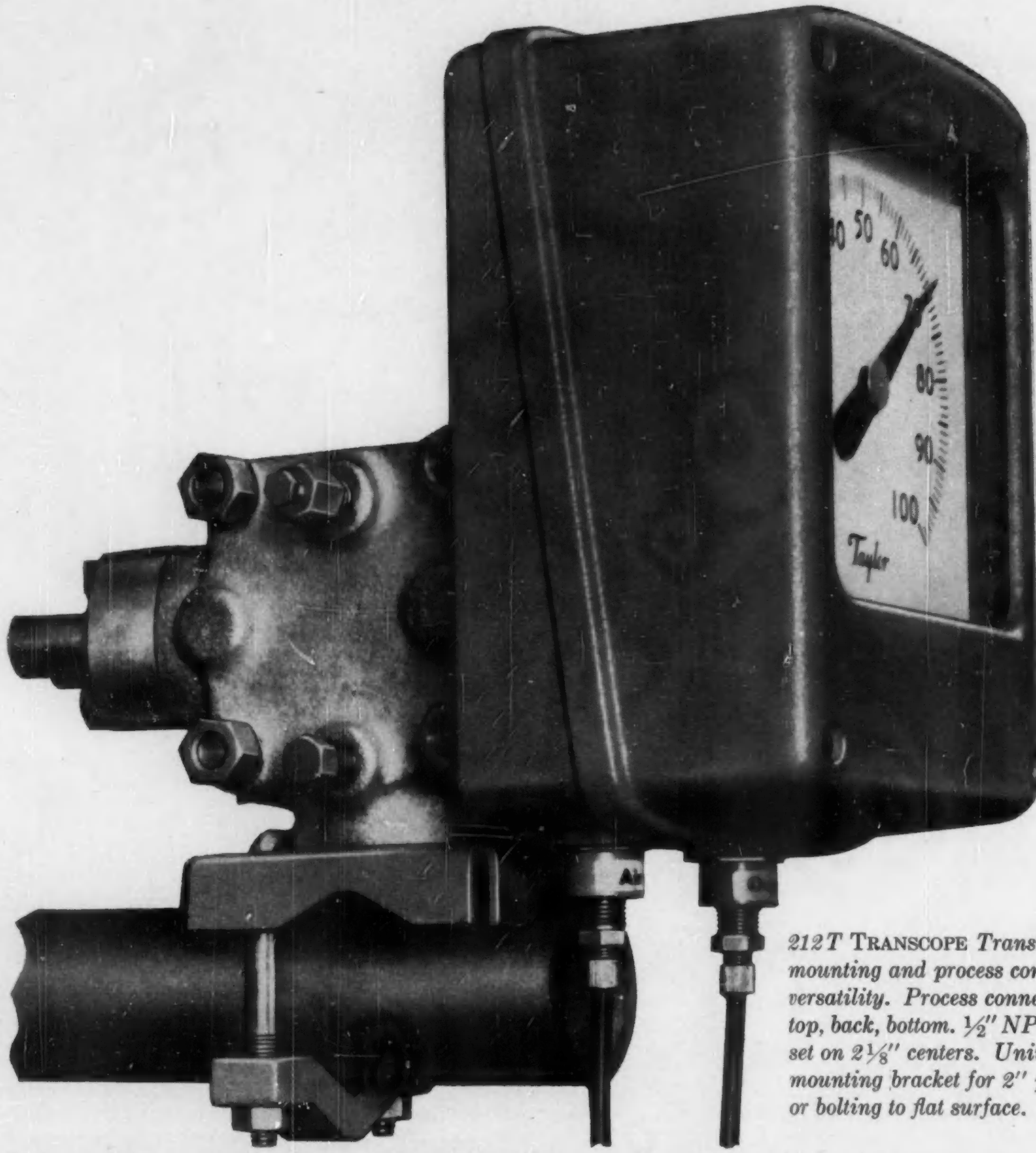
Any variation in feedrate oscillator frequency is reflected in all subsequent operations including the commanded slide velocity. The feedrate oscillator normally operates at 166 kc, but with an external override the operator can adjust its frequency lower or higher to a limit of 200 kc. The automatic internal override, see figure, depresses the frequency from the operating value to about 5 kc, and slide velocity is reduced proportionally.

To achieve the wide frequency range required, two oscillators—one fixed in frequency at 870 kc, and the other tunable between 875 and 1,070 kc—are heterodyned to get a difference signal of 5 to 200 kc. A low pass filter removes the unwanted basic oscillator frequencies and their sum.

The variable oscillator frequency is controlled by a dc voltage derived from variable width servo error pulses. First the pulses are integrated to obtain a varying dc voltage, and then this voltage is differentiated to obtain a signal proportional to rate of change and hence to error acceleration. This signal, fed through an OR gate and summing circuits, lowers the feedrate frequency whenever acceleration forces exceed a safe limit. Any axis can depress the feedrate, but all axis velocities are reduced in the same proportion to maintain the coordinated relationship needed for contouring. Each axis has a threshold adjustment to allow optimum acceleration.

The problem of controlling deceleration is quite different. To decelerate and stop at a specified point requires some anticipation of the stopping point. Deceleration control is set in motion by a tape controlled signal and a timing pulse that signals when 40 percent of the block or cycle is completed. Then a ramp is generated to depress the frequency. The slope of this ramp is adjusted so that the feedrate is approximately 6 ipm when the last data pulse is metered. If the velocity is in the contour cutting range at the start, then at shutoff it is below 1 ipm; little overshoot results.

By keeping forces within safe limits for the machine tool, there should be less wear on gears and feedback elements. Conventionally, to obtain path control it was necessary to have a tight servo system with high stall torque drives. In general, this meant using hydraulic drive systems for contouring applications. IFRO makes possible an all-electric contouring system because velocity changes are kept within the capability of the servo loop. This eliminates torque motors, servovalves, and hydraulic power supplies, and simplifies the over-all system in contouring applications where high torque is not required for cutting.



212 T TRANSCOPE *Transmitter has mounting and process connection versatility. Process connections at top, back, bottom. ½" NPT fittings set on 2⅛" centers. Universal mounting bracket for 2" pipe, or bolting to flat surface.*

Calibration linear with flow *eliminates need for sectionalized charts.*

Taylor Instruments

Want a
superior DP
transmitter?

THE 212T TRANSCOPE® TRANSMITTER

performs better

AND . . .

gives linearized
flow output without
changing parts

AND . . .

with no premium
price ! ! !

The Taylor 212T TRANSCOPE Transmitter is first and foremost a superior DP Transmitter. In addition, however, when used for flow it can be calibrated to give linear output without changing parts. Check these plus features that are all yours with *no premium price tag.* Then see your Taylor Field Engineer for a demonstration or write for **Bulletin 98413.** Taylor Instrument Companies, Rochester, New York, and Toronto, Ontario.

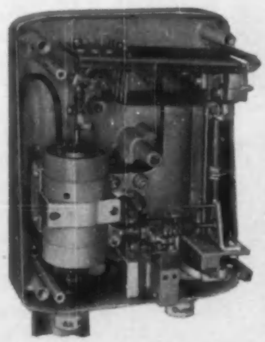
- **High Accuracy**—within ½% of output.
- **Liquid-filled primary unit means:**

  Positive overrange protection. Hydraulic overrange protection to full body rating in either direction.

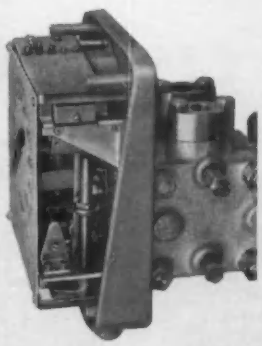
  Isolation of internal parts. Working parts—except diaphragms themselves—are exposed only to non-corrosive silicone oil.

  Built-in damping. Effective pulsation damping occurs at frequencies greater than approximately 2 cycles per second.

- **Exceptional Rangeability.** 20 to 250″ water for differential pressure, 20 to 175″ water for flow. Zero suppression and elevation available.
- **Servo power for square root extraction.** Linear output is a real money saver when applied to computer control or ratio and cascade control systems.
- **Linearized flow** eliminates need for sectionalized charts.



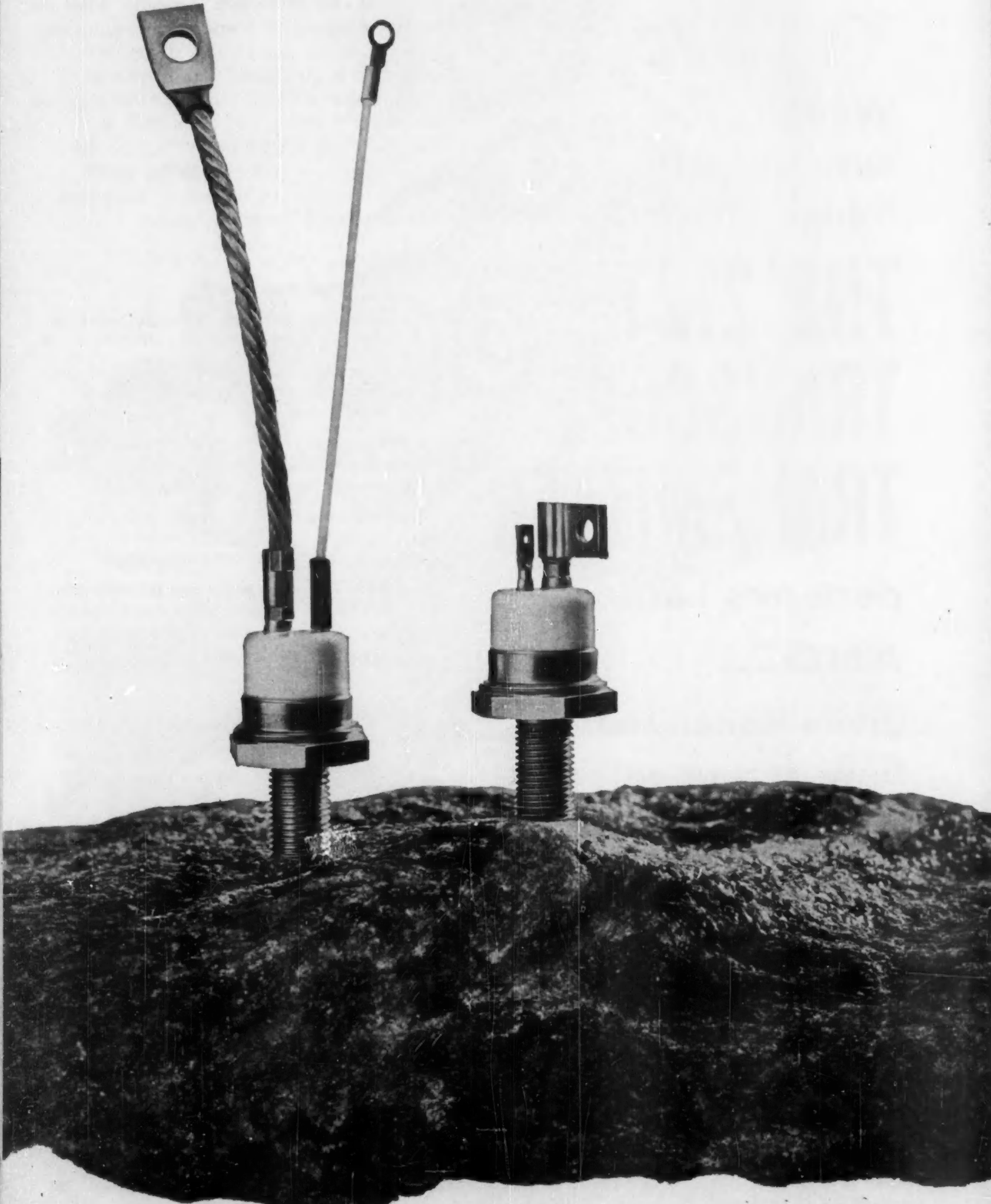
Open case design provides free access for maintenance.



Diagonally split case gives easy access for all adjustments.

MEAN ACCURACY FIRST

SEMICONDUCTOR NEWS: FROM WESTINGHOUSE AT YOUNGWOOD



General Electric Makes Eddy-current-coupling Drives

And they're dependable drives. The complete line includes water-cooled and air-cooled eddy-current couplings. We call them KINATROL* drives. Ratings are from 1 to 150 horsepower, operating from standard a-c power.

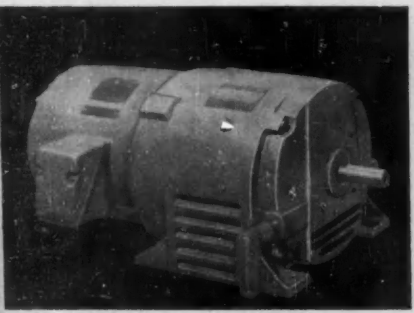
A General Electric KINATROL drive is not just another eddy-current coupling. For instance, in the water-cooled coupling, water control is packaged. You'll see much less external piping. Furthermore, the coupling is protected from flooding—and the air gaps are dry, preventing corrosion.

KINATROL couplings are compact, field proven and dependable. General Electric has had a good deal of experience in the engineering, manufacturing, and application of packaged adjustable-speed drives. And we know how important service is to a customer.

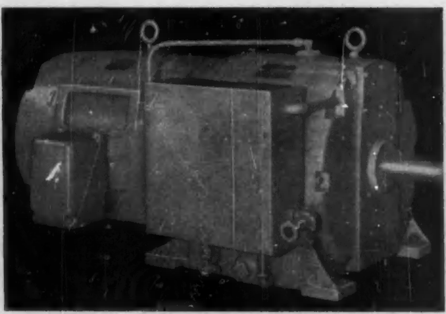
KINATROL —a good product, with the kind of service you can depend on. Please call your nearest General Electric Sales Office for further details.

*Trademark of General Electric Company

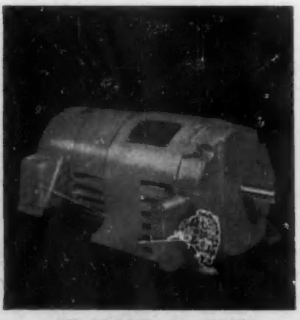
821-07



AIR COOLED, 7-1/2 to 100 HP



WATER COOLED, 25 to 150 HP



AIR COOLED, 1 to 5 HP

DIRECT CURRENT MOTOR AND GENERATOR DEPARTMENT

GENERAL ELECTRIC

ERIE, PENNSYLVANIA

NEW PRODUCTS

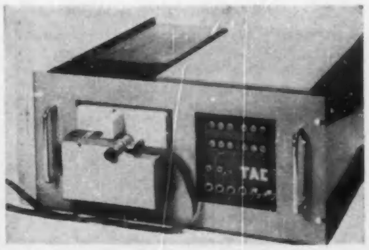
COMPUTER FINDS CORRELATION

function in real time.

This CORE computer finds the cross or autocorrelation integral (see page 88 for explanation of this function) on line by using two 400-channel ferrite core memories. One memory stores continuously the last 400 ordinates of one time function. Ordinate spacing is based on the stepout interval (τ) chosen, from 5 millisec to 5 sec. Memory is regularly scanned at the beginning of each new interval in real time, and memory contents are sequentially multiplied with the ordinate of the second time function existing at that time. Scanning and multiplying take only a fraction of the shortest interval of 5 millisec. Product ordinates are fed into and stored in the second memory. Each channel thus accumulates the sum of the products corresponding to a single correlation point. Entire memory accumulates full 400-point correlation. Function is displayed on oscilloscope and can be fed to other data devices. Unit could be used to give continuous measurement of system transfer function in real time without interrupting the process. The computer could also be used for correlation of an unknown function with a known waveform by inserting the known function in one memory. The device is housed in two cases, each measuring $8\frac{1}{2}$ x $10\frac{1}{2}$ x $21\frac{1}{2}$ in. and weighing 35 lb. Price: $26,950.—Mnemotron Corp., Pearl River, N. Y.

Circle No. 309 on reply card

THREE NEW COMPUTERS



FOR AUTOMATIC CONTROL

Designed to meet the need for a simpler and less expensive computer for control and data assimilation, TAC (Transistorized Automatic Control unit) sells for $14,750. Solid state computer has a temperature controlled magnetostrictive line memory of 500-900 28-bit words. Device can be used as a small process control computer or as a satellite computer in larger installations, to automatically check out wiring, as a quality tester, or as a versatile EDP component, since it is directly compatible with other computers. Design simplicity allows operators to learn programming in a few hours.—Dale's Associates, Culver City, Calif.

Circle No. 310 on reply card

STORED LOGIC

First industrial control computer to use stored logic, the TRW-530 is so versatile it can be used as a control computer, a scientific problem solver or a general purpose data processor. Its command structure is easily changed, being in the memory rather than in machine wiring. The TRW-530's 18-bit word length has 32,000-word capacity in a random access magnetic core store and 190,000 additional words in a supplemental magnetic drum. Memory cycle time is 6 microsec per word. Typical program operating speed is 10,000 calculations per sec.—TRW Computers Co., Div. of Thompson Ramo Wooldridge, Inc., Canoga Park, Calif.

Circle No. 311 on reply card

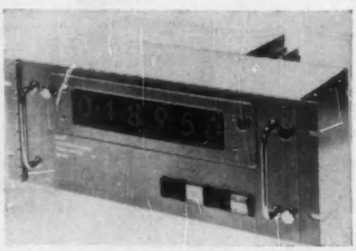
HIGH SPEED GP COMPUTER

DDP (Digital Data Processor) is a single address, parallel, binary, stored program general purpose computer. The 19-bit model has a 5-microsec, 4,000 or 8,000-word magnetic core memory, with additional memory ca-

pacity available. Access time is 2.5 microsec, read-write cycle time between accesses is 5 microsec. Add time is 3 microsec; average multiply time, 36 microsec; and average divide time, 45 microsec. The DDP has sufficient input/output flexibility (16 channels under program control) to handle real-time computations. Computer also features an interrupt mode for real-time operation, 64 commands, and an index register. Basic input/output is paper tape at 500-1,000 characters per sec. Price: $120,000-$400,000.—Computer Control Co., Inc., Los Angeles, Calif.

Circle No. 312 on reply card

SYSTEMS



PIPELINE TELEMETRY

The SD-102 accumulated count data transmission system is a low-cost system designed for remote display and recording of data from various meter inputs on pipelines. The network includes error and safety checks and features high reliability and easy installation and maintenance. Transmission is possible over commercial telephone lines or on private AM, tone, or FSK channels. Data are transmitted as six-character decimal digit message. Readout can be programmed automatically or called for on demand. The system is made up of a receiver (shown above), printer, and any number of remote transmitters.—Datex Corp., Monrovia, Calif.

Circle No. 313 on reply card

CLOSED-LOOP COMPUTER

Closed-loop control of industrial processes is possible with the expanded version of this manufacturer's 1710 solid state control system. Used with the 1620 computer are two new units: a 1711 data converter, Model 2 and a 1712 multiplexer and terminal unit. The 1712 contains interconnection terminal points between process equipment and the 1710. The 1711, Model 2 accomplishes data manipulation, recording, and control by connection through the 1712 to measuring or control devices. The 1620, unchanged, has 20,000 to 60,000 positions of core storage. The system rents for $3,000 to $6,000 a month and sells for $125,000 to $250,000. —International Business Machines Corp., Data Processing Div., White Plains, N. Y.

Circle No. 314 on reply card

IMPROVED EDP SYSTEM

A ninefold increase in magnetic tape speed and a core memory with double the capacity of former models are the features of the advanced 301 data processing system. Magnetic tape units now have a speed of up to 66,000 characters per sec, and high speed memory capacity is now 40,000 alphanumeric characters. Up to 12 tape stations can be operated in the computing system. Since two of these can be operated simultaneously, transfer rates to and from the computer of 132,000 characters per sec are possible. Monthly rental rates range from $3,000 to $25,000 with delivery possible in nine months.—Radio Corp. of America, Electronic Data Processing Div., New York, N. Y.

Circle No. 315 on reply card

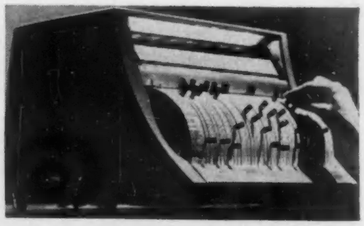
DATA HANDLING & DISPLAY

THREE EDP UNITS

Hypertape is the fastest magnetic tape system now commercially available, being able to read or write 170,000 eight-bit alphabetic, 340,000 four-bit numeric, or 250,000 typical alphanumeric characters per sec. Designed

for use with the manufacturer's 7074, 7080, or 7090 computers, the new tape system uses a cartridge loading technique which takes just 20 sec, eliminating the need to handle the tape itself. (Cartridge is shown being loaded in right-hand unit on page 128.) Cartridge can be removed at any point and is automatically unsealed or resealed when loaded or unloaded. A single capstan drive is used, and the tape touches the capstan only on the nonrecording surface. Capacity is 25 million characters on 1,800 ft of tape. Tape can be read backward for faster sorting. Read access time is about 4 millisec. The drive and control units (7340 and 7640) rent for a total of $4,700 a month and sell for $296,000. Deliveries will start in mid-1963. (316) Also new from this manufacturer are compatible data transmission units that can communicate with each other or with twin units at up to 300 characters per sec. The 7702 terminal ($1,300 a month or $58,000) is for magnetic tape, and the 1013 ($800 a month or $44,000) is for cards. (317) Another product, a 188 collator for punched cards, uses core storage instead of relays and transistors instead of tubes. With 16 control positions the 650-cpm unit rents for $575 a month, sells for $30,-750. (318)—International Business Machines Corp., Data Processing Div., White Plains, N. Y.

Circle No. 316, 317, or 318 on reply card

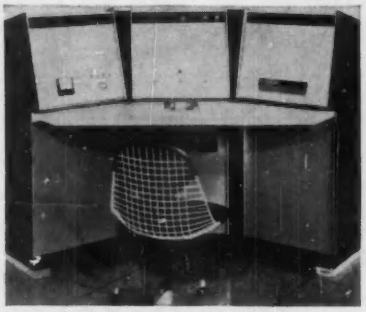


GIVES COMPUTER VOICE

This computer inquiry device, Unicall, allows a computer to "talk" to data set operators with a recorded voice reply. Designed to be used with the manufacturer's Real Time computers, the easy-to-operate unit accepts standardized inquiries, read in by setting 40 sliding levers keyed to a lever-selected format guide and a display window. It transmits the signals through an inexpensive telephone company data handler over telephone lines to the central computer. Answers to the questions are recorded as voice

signals on a magnetic drum. After checking reservation status for an airline, credit rating, merchandise inventory, etc., the computer sends the voice answer back to the Unicall. Entire transaction takes less than 5 sec. Unit rents for about $30 a month and sells for approximately $1,350.—Remington Rand Univac Div., Sperry Rand Corp., New York, N. Y.

Circle No. 319 on reply card



SOLID STATE MONITOR

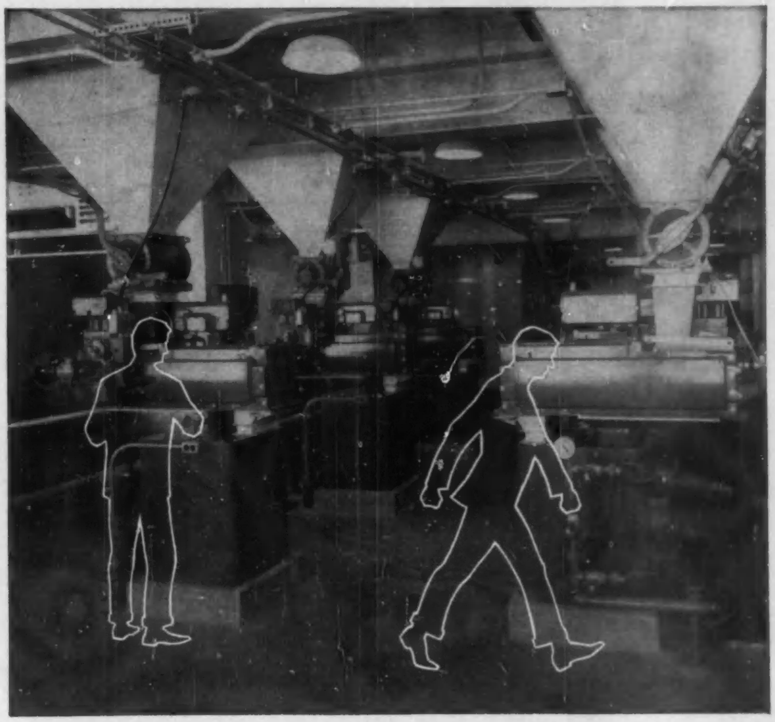
Except for its printer, the new Panastat THOR VII (Transistorized High Speed Operations Recorder), uses all solid state components. Designed for any continuous process, the monitor prints out (on adding machine tape) alarm points going off or returning to normal in time sequence to 1 millisec apart. Alarms are never lost or scrambled even if memory is filled. Patented printer uses red printout to indicate point going off normal and black for return to normal. Chassis are available in increments of 20 points up to a maximum of 999 points. Memory is transistorized with capacity of 10 25-bit words.—Panellit Div., Information Systems, Inc., Skokie, Ill.

Circle No. 320 on reply card

COMPACT DATA ACQUIRER

The APD (Analog to Pulse Duration) is said to be the first compact inexpensive data acquisition system available to industry for process control applications. The APD can be used with thermocouples, resistance thermometers, or strain gage transducers. Accuracy is to within one part in 1,000 full scale on any range. Solid state modular circuitry is used. Sampling rate is 20 per sec and so unit is suitable for static or quasistatic data. Display of reduced data is by multi-filament numeric tubes. Excluding output equipment, the unit requires only 7½ in. of a standard rack and consumes about 10 watts.—Genisco, Inc., Los Angeles, Calif.

Circle No. 321 on reply card



NEW PRODUCTS

PLUS . . .

(322) New high capacity **multichannel data recording system** with high precision has been introduced by **Mnemotron Corp.**, Pearl River, N.Y., at $3,495 complete with tape transport . . . . (323) **Omnitronics, Inc., Sub. of Borg-Warner Corp.**, Philadelphia, Pa., has announced a versatile, low cost, **bidirectional paper tape handler** for 5 to 8-in. reels at tape speeds to 40 ips . . . . (324) A new series of **modular block tape readers** priced from $1,625 with control unit has been designed for restricted panel space by **Automation Div., Electronic Engineering Co. of Calif.**, Santa Ana, Calif.

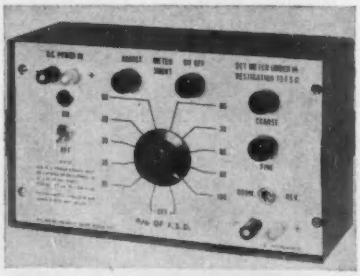
Circle No. 322, 323, or 324 on reply card

RESEARCH, TEST & DEVELOPMENT

LOW COST DVM

This all electronic Model 650 digital voltmeter has five-digit display and sells for just $1,850. Range is from ±0.0001 to ±1,200 vdc. Absolute accuracy is to within 0.05 percent ±one count. Input impedance is essentially infinite except on the 1,200-volt range where it is 20 megohms. Device also features internal calibration cell, four-position input filter, and automatic polarity sensing and display. A direct printer is available.—Franklin Electronics, Inc., Bridgeport, Pa.

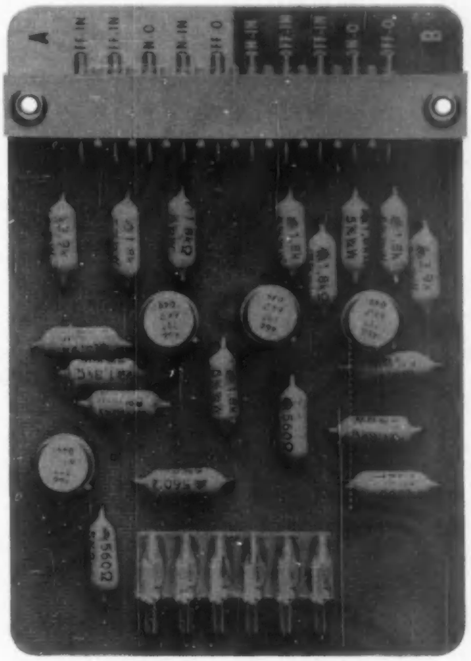
Circle No. 325 on reply card



TESTS METER LINEARITY

Speedy evaluation of moving coil dc meter linearity is possible using this accurate, portable instrument. The Model 113 tester can allow the use of

(Continued on page 137)



NEW FROM

DELCO RADIO

AN ADVANCED MACHINE CONTROL SYSTEM

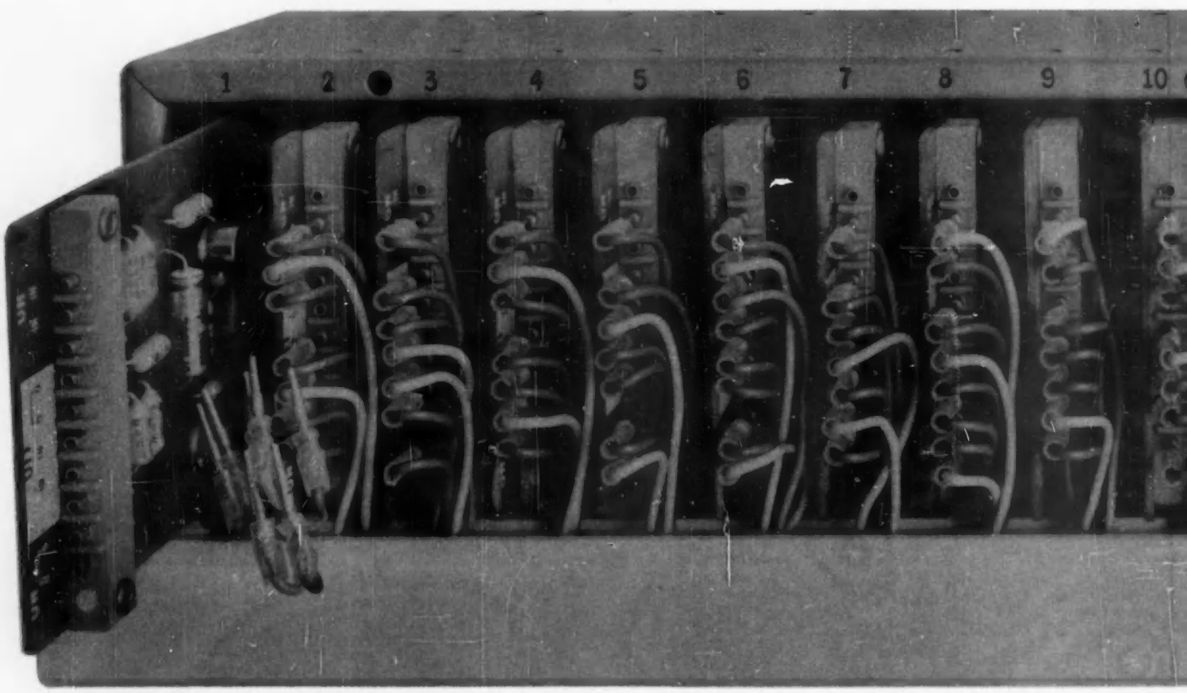
Del-Con

* No Moving Parts
* Faster Operating Speeds
* Easy Programming
* Increased Reliability

Del-Con's fully transistorized printed-circuit boards in actual size.

Del-

... A NEW CONCEPT OF MACHINE CONTROL ... OFFERING THESE BENEFITS—



Here's an advancement in the field of machine control that saves time, money, manpower and downtime. It's Del-Con, Delco Radio's all new, fully transistorized static machine control system. Del-Con performs machine control logic functions with increased speed and reliability . . . giving it unmatched superiority over systems incorporating the use of magnetic relays.

NO MOVING PARTS—Del-Con differs from older systems using magnetic relays through its use of transistors. It is completely static. This provides Del-Con with greater reliability, longer life and reduced downtime.

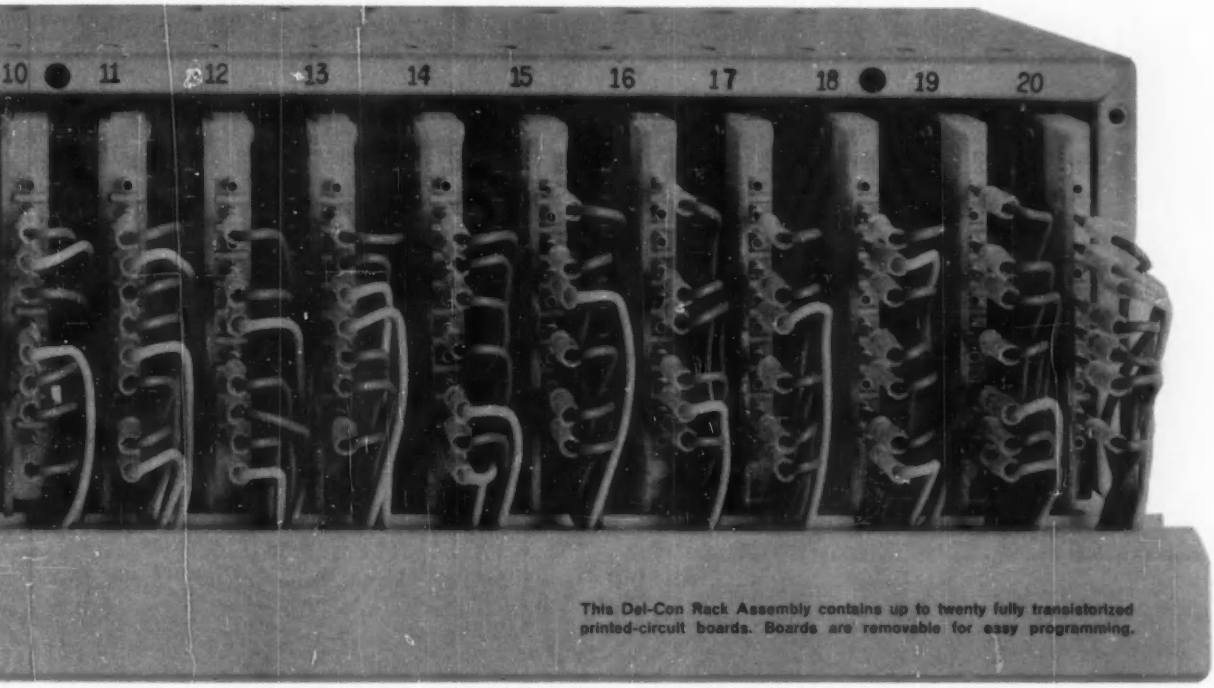
GREATER OPERATING SPEEDS—The use of fully transistorized printed-circuit boards gives Del-Con operating speeds within the range of 10 microseconds.

EASY PROGRAMMING is accomplished from the front of the rack through the use of taper pin wiring connections.

REMOVABLE BOARD DESIGN—Increases the ease of programming and replacement. Twenty printed-circuit boards may be placed in a Del-Con rack. These boards may be programmed through the use of taper pin connections as described above. This allows programming by relatively untrained personnel.

-Con

- NO MOVING PARTS
- FASTER OPERATING SPEEDS
- EASY PROGRAMMING
- INCREASED RELIABILITY



This Del-Con Rack Assembly contains up to twenty fully transistorized printed-circuit boards. Boards are removable for easy programming.

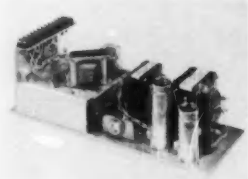
Del-Con is superior to magnetic relay systems because it uses transistors in basic logic circuits, such as MEMORIES, ANDS, ORS, NOTS, NORS, amplifiers and timers.

To further simplify Del-Con, these functions are combined on changeable printed-circuit boards as follows:

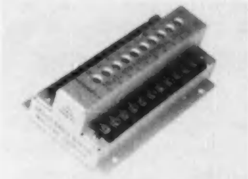
1. NOR board—contains 2 NOR elements 2. MEMORY board 3. Timer board 4. OR board—contains (2) four-input diode OR networks 5. OR power amplifier boards, 20-watt 6. NOR power amplifier boards, 20-watt 7. 50-watt power amplifier board 8. Dual NOR-Dual NOT board 9. AND board—3-input.

Taper pin connectors for programming are located at the top end of these boards for logic connections and an ELCO type connector is located at the bottom to plug into the power supply lines. These lines are printed wiring which run the length of the rack and terminate outside at a screw terminal strip.

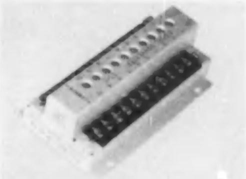
Two important benefits of the Del-Con system involve input switches and output solenoids. Much longer electrical life for the input limit switches exists because the switches control a very small amount of power. Output devices in Del-Con, such as solenoid coils, will have longer life since they are not subjected to high induced voltages which are often generated in systems using relay contacts.



The PS-3531 power supply provides supply voltages and current necessary to operate up to 70 logic elements in the "ON" condition.



OUTPUT MONITOR provides —24 VDC and power amplifier output connections to the load; monitors ten independently actuated loads.



SIGNAL CONVERTER will convert up to ten signals and provide an indication of pilot device activation using neon indicator lamps.

For complete engineering data or applications assistance on Del-Con Static Machine Controls, contact the Delco Radio Sales Office.

DELCO RADIO
DEPENDABILITY
RELIABILITY

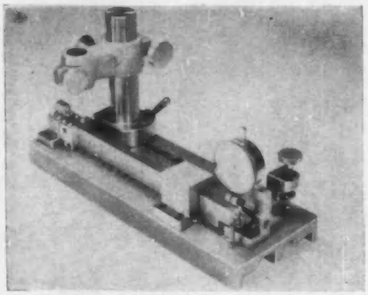
Division of General Motors
Kokomo, Indiana

NEW PRODUCTS

(Continued from page 132)

more economical meters, since linearity may be more important than absolute accuracy, as found in very expensive meters. The tester checks 10 points with an accuracy to within ±0.2 percent. Meters tested may have full scale sensitivity from 50 microamp to 1 milliamp. Price: $99.50.—IB Instruments, Cleveland, Ohio.

Circle No. 326 on reply card



CHECKS LVDT's

The precision built Model TK-501 Micro-Checker provides a mechanical means of checking displacement transducers such as LVDT's or strain gage and variable reluctance types. The transducer to be tested is clamped to a mounting bracket and positioned by a knob so that the transducer extension touches a lever. An adjusting screw displaces one end of the lever, deflecting a preset dial indicator. A comparison can thus be made between actual transducer deflection and its voltage output. Displacements as small as 1 microin. can be easily detected. Price: $400.—Techni-Rite Electronics, Inc., Warwick, R.I.

Circle No. 327 on reply card

HAS VARIABLE RISE TIME

The Model 203 pulse generator has an output whose rise and fall time can be varied linearly from 20 nanosec to 2 microsec, permitting simulation of most of the conditions produced in a variety of transistor switching circuits. Pulse repetition rate is 30 cps to 3 Mcps. Unit will trigger on any positive or negative input waveform of 6-volt minimum amplitude at frequencies as low as 30 cps. Delay time and output pulse width can be varied continuously in four decade ranges from 50 nanosec to 1 millisec. Output is a positive or negative pulse of 15 volts max into an external load of 50 ohms.

NEW PRODUCTS

Rack mounting unit is 7 in. high and 14 in. deep, weighs 20 lb, and sells for $795.—Rese Engineering, Inc., Philadelphia, Pa.

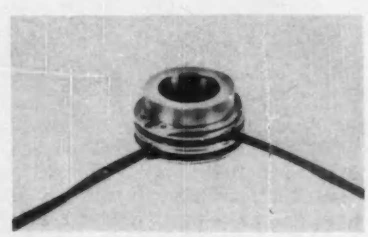
Circle No. 328 on reply card

LAB CONTROLLER

This portable instrument is useful in laboratories for precise automatic regulation of temperature. The Bookstat is also applicable to measurement and control of pressure, vacuum, or liquid level. Control to 0.1 deg C is easily maintained. The unit can provide proportional, on-off, or high limit alarm control as well as an output signal for recorders.—Brook Instrument Co., Inc., Hatfield, Pa.

Circle No. 329 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



FORCE WASHERS

These miniature load cells are designed in the shape of regular bolt washers. The force washers come in standard bolt sizes of 3/16 to 1 in. in diam., and are temperature-compensated for temperatures of 50-250 deg F. Load ranges from 5,000 to 35,000 lb. Temperature compensation is to within better than 0.5 microin./in./deg F. Linearity, re-

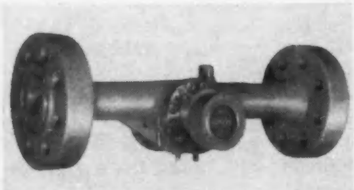
peatability, and hysteresis are to within ±1 percent of full scale. Price: $68.40-100.80.—Lockheed Electronics Co., Avionics and Industrial Products Div., Los Angeles, Calif.

Circle No. 330 on reply card

GAS DENSITY CELL

Continuous, precise measurement of gas density in pounds per cubic foot is possible using the new Type 35 gas density cell. The device produces a differential pressure directly proportional to density. Combined with a pressure differential across a primary device, this measurement allows determination of mass flow. The differential pressure output of the cell is measured by a standard instrument which may be located up to 50 ft away. Densities to 7.8 lb/cu ft can be measured. The unit is 9½ in. in diam at its widest part and is 15 in. high; weight is 48 lb. Price: $375.—The Foxboro Co., Foxboro, Mass.

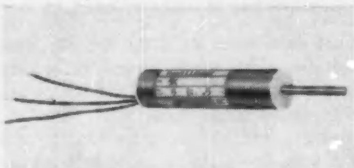
Circle No. 331 on reply card



HIGH PRESSURE FLOWMETER

This 2-in. Whirl-Flo flowmeter is an economical and accurate unit for measuring gas or liquid flow. Pressure rating is 5,000 psig. The Model L2S-H for liquid flow and the G2S-H for gases operate on the vortex-velocity measurement principle. A wide variety of readouts are available including simple totalizer or complex multiple-compensated integrators. Special transducers to feed signals to computers and telemetry transmitters are also available. Price: about $800.—Rotron Controls Div., Rotron Manufacturing Co., Inc., Woodstock, N. Y.

Circle No. 332 on reply card



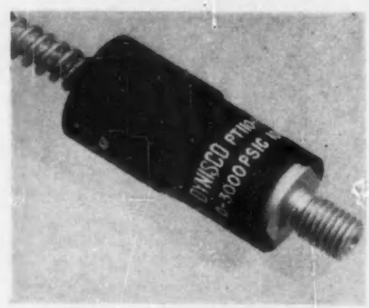
TRANSLATORY POTS

Either cermet or wirebound elements are offered in this line of custom built translatory potentiometers. The cermet elements offer greater tempera-

NEW PRODUCTS

ture capability and lifetime: −75 to +200 deg C and 5 million cycles. Resistance ranges for both types vary from 200 to 140,000 ohms per in.—Helipot Div., Beckman Instruments, Inc., Fullerton, Calif.

Circle No. 333 on reply card



NOVEL TRANSDUCER DESIGN

A unique design concept is used in this new pressure transducer. Pressure medium is admitted to the space between two concentric cylinders to expand the outer cylinder and compress the inner one. A pair of circumferentially wound strain gages are bonded to the inside of the inner cylinder wall, and another pair on the outside of the outer cylinder form a complete four active arm Wheatstone bridge. The design of the Model PT110 allows nonlinearity of only 0.15 percent and high thermal stability. Units are available in ranges from 500 psig through 10,000 psig.—Dynisco, Div. of American Brake Shoe Co., Cambridge, Mass.

Circle No. 334 on reply card

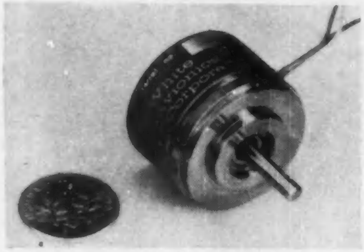
CONTROLLERS, SWITCHES & RELAYS

IMPROVED REED SWITCH

Two new series of magnetic dry reed switches eliminate the need for biasing to obtain a NC switch. Both series include switches with spdt Form C contacts with 1½-in. glass length and 0.230-in. max diam. Contact resistance for both is 25-40 milliohms. The DRG-DT switches are hermetically sealed in an inert atmosphere and have contact ratings of 3 watts dc resistive, 10 watts ac resistive at 110 volts or ½ amp ac max. The DRG-DTH

switches are pressurized in pure hydrogen and have contact ratings of 20 watts dc resistive, 40 watts ac resistive at 250 volts or 1 amp ac max. Actuating time for either is 0.5 millisec and up, and contact bounce is 2 millisec NC or 1 millisec NO. Prices start at \$3.—Hamlin, Inc., Lake Mills, Wis.

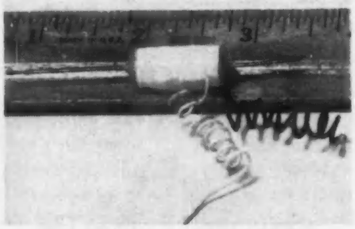
Circle No. 335 on reply card



NO WEARING CONTACTS

This solid state rotary switch eliminates problems evolving from wearing contacts. The spdt switch uses a slotted disc passing a beam of light to sensitive diodes. Virtually any switching sequence can be provided with an angular accuracy to within 0.25 deg. Current capacity is 150 ma at 28 vdc. Unit will operate in severe environments at temperatures up to 100 deg C. Price: \$250.—White Avionics Corp., Plainview, N. Y.

Circle No. 336 on reply card



TINY RELAY

This ¼-oz relay is rated at up to 20 million operations at low load or 3 million at maximum load. Maximum contact rating is 4 watts with coil power of 0.06 watts. Operate time is 0.8 millisec. The unit illustrated has 6-vdc, 10-ma coil and contacts hermetically sealed in inert gas. Price each in orders of 1,000: \$2.70—New Products, Inc., Raleigh, N. C.

Circle No. 337 on reply card

PLASTIC SWITCHES

Applications requiring long life on continuous duty under extreme environmental conditions can use this new line of precision rotary switches to advantage. The switch plate is of

conductive plastic molded to a plastic insulator base. High wear characteristic of the plastic surface and the low coefficient of friction between it and the precious metal wiper allow high wiper pressure. Coupled with rugged construction, this feature is said to give low torque devices with signal characteristics essentially independent of speed and also extreme vibration, shock, and acceleration resistance. Units have been tested to 10 million revolutions at 600 rpm. At light loads a minimum 300 million revolution life is claimed. Prices range from \$30 to \$1,500.–Markite Corp., New York, N. Y.

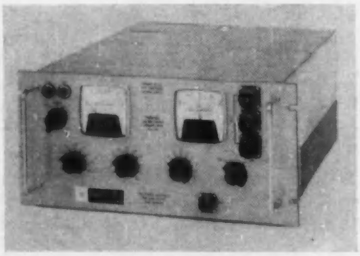
Circle No. 338 on reply card

PLUS . . .

(339) The Model 610GE **explosion-proof pressure switch** now available from **Custom Component Switches, Inc.**, Burbank, Calif., is one-quarter the size of similar switches currently available. . . . (340) **Thermel, Inc.**, Providence, R. I., has made available a subminiature **snap-acting thermal switch** (numbered 3001-2) that is hermetically sealed and especially vibration and shock resistant. . . . (341) A new **alarm system** for liquid flow control now on the market from **Terriss-Consolidated Industries,** New York, N. Y., senses slowdown in any fluid's flow and sells for \$85.

Circle Nos. 339, 340, or 341 on reply card

POWER SUPPLIES

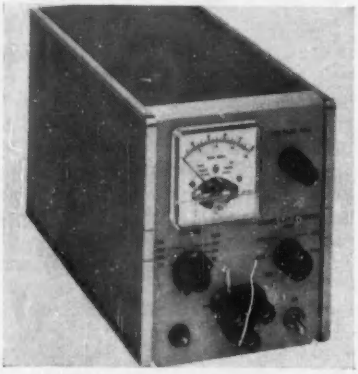


PRECISION SOURCE

This stable laboratory supply unit offers precision selection of output from 300 to 5,060 volts by turning a dial. Output is regulated to within 0.001 percent even with line variations as high as 10 volts in the 115-

volt input. Load regulation, no load to full load, is to within 20 mv plus 0.001 percent. Ripple is 1 mv rms max. Price for the Catalog No. 1514 supply is $580.—Carad Corp., Palo Alto, Calif.

Circle No. 342 on reply card



EXTERNALLY PROGRAMMED

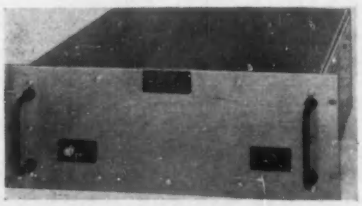
Output of this dc supply can be programmed by external resistance for fast repetitive testing. The Model 723A has regulated, continuously variable output of 0-40 vdc that can be changed by a front panel control or with an external resistance at 50 ohms/volt rate. Full load output current is 500 ma. Ripple and noise are less than 150 microvolts rms. Price: $225.—Hewlitt-Packard Co., Palo Alto, Calif.

Circle No. 343 on reply card

EMERGENCY SOURCES

Maintenance of operation of critical equipment in case of commercial power failure is the aim of these instantaneous emergency power sources. Up to 750 va of 115-vac, 60-cps power can be supplied from reserve battery sources of 120, 130, or 140 volts. Full load can be picked up within 50 millisec.—Cornell-Dubilier Electronics Div., Federal Pacific Electric Co., Fuquay Springs, N. C.

Circle No. 344 on reply card



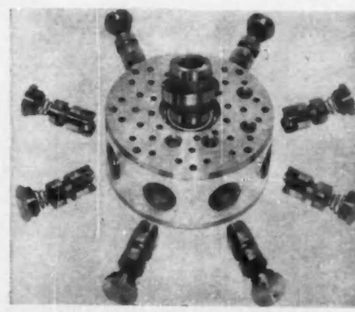
ON-OFF REGULATED

A new principle of regulation makes these dc supplies regulated to within 50 mv for a 10-volt line change and

100 mv from no load to full load. These switching type of supplies use on-off regulation to give increased efficiency and lower cost. Ripple is 35 mv rms. Required input is 105 to 125 vac at 48-62 cps. Ambient temperatures of 0-50 deg C can be tolerated. Units are available for outputs of 10-20, 18-26, 24-32, and 30-52 vdc and in four current handling capacities, 10, 20, 30, and 50 amp for a total of 16 models. Prices range from $450 to $1,125.—Consolidated Avionics Corp., Westbury, N. Y.

Circle No. 345 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



UNIQUE RADIAL MOTOR

Eight diametrically opposed pistons drive this novel Acradrive/22 motor through needle-bearing rollers acting on a two-lobe cab which encircles the hollow center spindle. Speed range can be from a peak of 500 rpm through a recommended maximum speed of 350 rpm down to 1 rev in 41½ days. Device uses 22 cu in. of oil with two four-piston banks connected in parallel or 11 cu in. with banks in series. Pressure rating is just 500 psi. Theoretical torque is 3.52 lb-in./psi at full capacity. The motor also features extreme stiffness, no backlash, and high acceleration. Unit is 12½ in. in diam by 6 in. and weighs 138 lb. Originally designed for machine tool positioning systems, the motor has since been specified for tracking radars.—Cimtrol Div., Cincinnati Milling Machine Co., Cincinnati, Ohio.

Circle No. 346 on reply card

CUSHION ACTION VALVE

Line shock induced by valve operation in hydraulic circuits is minimized by the controlled cushion action of this new two-way solenoid valve. A tapered valve disc maintains linear flow throughout gradual opening and closing cycles. When equipped with a metering adjustment, the Type 250's flow may be regulated from 0 to 1 gpm at 400 psi through a $\frac{1}{16}$-in. orifice. Opening or closing time is $\frac{1}{4}$ sec. The valve operates on voltages of 6-440 vac or 6-220 vdc. A variety of housings is available. The valve is $1\frac{3}{8}$ in. in diam, 3 in. high, and weighs 16-22 oz. Unit list price: $12–Allied Control Co., Inc., New York, N. Y.

Circle No. 347 on reply card

COMPUTER MOTOR

This new dc precision motor has been especially developed for computer drives where operation is almost entirely under a stalled condition. Model 4026-4 operates on 50 volts to give an output of 500 oz-in. at stall and a no load speed of 1,500 rpm. The 40 Frame motor is 4 in. in diam and 8 in. long.–Eicor Div., Indiana General Corp., Oglesby, Ill.

Circle No. 348 on reply card

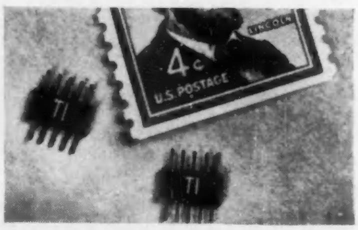
DIGITAL SERVOMOTOR

This high-speed digital servomotor rotates bidirectionally in increments of 15 deg when 28 vdc is switched sequentially between its three motor windings. Rate of operation is 590

increments per sec with slewing rate of 1,200 increments per sec. Acceleration is greater than 90,000 rad per sec. Running torque is 0.9 oz-in., and the motor remains detented at 1.5 oz-in. Size 11 weighs 3.5 oz.—Digital Servo Corp., Sub. of Imm Industries, No. Hollywood, Calif.

Circle No. 349 on reply card

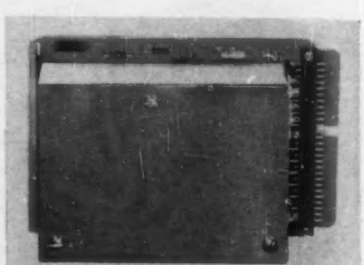
COMPONENT PARTS



SOLID MODULES

The new Series 51 line of Solid Circuit semiconductor networks includes six digital circuits that will handle 90 percent of all circuit functions in computers. Networks perform flip-flop, counter, NOR, NAND, and OR functions. Each of the silicon packages is $\frac{1}{4}$ x $\frac{1}{8}$ x $\frac{1}{32}$ in. The networks, each produced from a single slice of silicon, have current drains one-tenth that of many advanced conventional circuit types. Sample units are priced at \$95 and \$115; lots of 1,000 would sell for \$50-65. Circuits are available immediately.—Texas Instruments, Inc., Dallas, Tex.

Circle No. 350 on reply card



COMPACT SERIAL MEMORY

This digital serial memory features pulse delays (achieved by acoustical

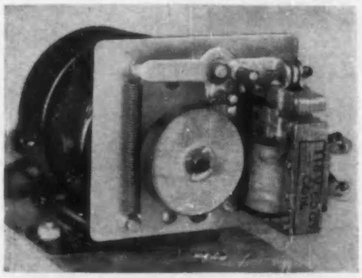
methods) of 20-100 microsec and operating frequencies of 8-16 Mcps. Capacity of the SM-40 is 1,600 bits, and input rate is as high as 16 million bits per sec, without the need for carrier modulation. Unit requires +12 volts at 60 ma, −4 volts at 100 ma, and −12 volts at 120 ma. Power dissipation is 2.6 watts. The compact plug-in unit weighs 1 lb and sells for $997.—Computer Control Co., Inc., Framingham, Mass.

Circle No. 351 on reply card

INTERSTAGE DELAY

Latest in this company's line of digital logic modules is a card-mounted Model M11 interstage delay module. Five inductive delay circuits provide a fixed delay of 0.75 microsec for interstage carry pulses. The module also has AND and OR gates for reading information into flip-flops in parallel. Price: $119.—Navigation Computer Corp., Norristown, Pa.

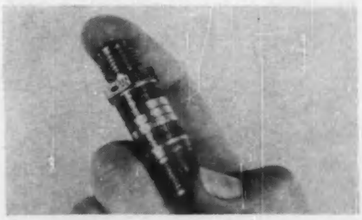
Circle No. 352 on reply card



STOPS MOTOR OVERTRAVEL

This low cost solenoid operated brake is suitable for stopping overtravel of motors in such applications as computer mechanisms and tape transports. The Instop has braking torque of 2-4 lb-in. for subfractional horsepower electric motors with shafts up to ⅜ in. The solenoid is furnished for ac up to 230 volts or dc as low as 12 volts. Price: about $5.65.—Midwest Automatic, Inc., Des Moines, Iowa.

Circle No. 353 on reply card

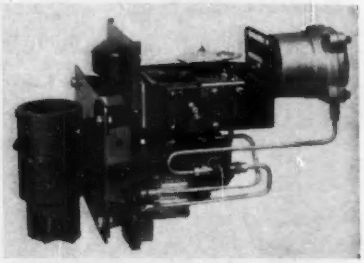


HEAVY DUTY SQUIB

The Model IN-113 heavy duty pyrotechnic initiator provides a high de-

gree of safety and reliability. The device contains a low brisance squib which will not fire at voltages as high as 250 vac rms applied continuously but will always fire at 500 vac rms (700 vdc) or more. Controlled burning rate allows igniting of secondary charges without detonation. The firing unit is completely shielded and filtered for protection against rf and other radiation.—Fleming Industries, Inc., Torrance, Calif.

Circle No. 354 on reply card



RATIO COMPUTER

This new vector ratio computer replaces a conventional ratio device and two square root extracting devices in pneumatic flow ratio control systems. Available in ratings of 3-5 psig, the instrument will sound an alarm or limit flow of one liquid when ratios pass a preset point. Output from the computer can be used as the measured variable for a controller. Accuracy of the computer is to within 1 percent. Price: $260.—Republic Flow Meters Co., Sub. of Rockwell Manufacturing Co., Chicago, Ill.

Circle No. 355 on reply card

ACCESSORIES

1-MICRON FILTER

The Microtube cartridge filter is said to be the first such element that al-

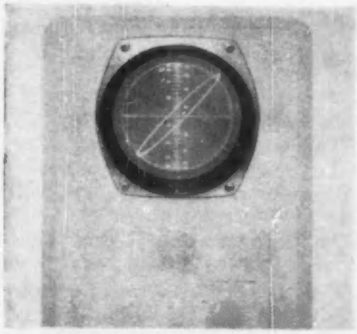
lows the removal of all particles larger than 1 micron from fluids in high tolerance missile and aircraft recirculating systems. The cartridge is $4\frac{1}{2}$ in. high by $1\frac{25}{32}$ in. in diam and meets MIL envelope specifications. It can be installed in existing ground support and test equipment with little if any system design changes. Rated flow at differential pressure of 40 psi is 4 gpm for MIL-H-5606A fluid at 80 deg F, 84 SUS viscosity. Maximum operating pressure is 200 psid. Price: \$48.—Millipore Filter Corp., Bedford, Mass.

Circle No. 356 on reply card

PROTECTS CIRCUITS

Only 2 millisec are required to disconnect an overloaded circuit when this new electronic circuit protector is used. The device continually recycles, constantly resampling for overload. The current-sensing device operates between 5 and 500 ma dc and has usable voltage range of 0-450 vdc. Recycle time is 4 sec with the load disconnected, and the unit repeats recycle time with overload present in less than 20 millisec. A pushbutton reset is provided, and a light glows to indicate overload. Protector operates on 110 vac, 60 cps.—Electronic Aids, Inc., Baltimore, Md.

Circle No. 357 on reply card



AIDS PHASE READOUT

Direct readout on an oscilloscope of phase relationship between any two synchronous waveforms is facillitated by the use of the Pha-ϕ-Scale accessory. The transparent, machine-engraved device replaces the standard grid recticule on the 'scope. A special vertical scale is calibrated in degrees and permits direct readout of the phase relationship as the Lissajous figure intercepts the axis. The unit can be used with any U.S.-made oscilloscope.—Walker Pacific, La Puente, Calif.

Circle No. 358 on reply card

WHAT'S NEW

(Continued from page 40)

conductor scientists. The company will produce custom designed miniature electronic circuits.

Transitel International Corp. has been formed in Paramus, N. J., by Baldwin-Lima-Hamilton Corp. and Industrial Process Engineers, Inc. to make solid state digital transmission systems and components. First products, including a new solid state annunciator and a servo digitizer, will be aimed at the industrial supervisory control market. The new company is the outgrowth of the Electronics Div. of Industrial Process Engineers.

Loral Electronics Corp. of New York has announced that it is about to enter the market with a line of electronic equipment and components to be handled by a new General Products Div. The company has been a supplier of systems for military applications. Jack Hebron, former general manager of the Ketay Dept. of the Norden Div. of United Aircraft Corp., has become the division's manager.

OPW-Jordan Div. has been acquired from the Dover Corp. by Richards Industries, Inc. and has been renamed the Jordan Valve Div. Richards Industries is headed by Gilbert B. Richards, Jr., former president of OPW-Jordan, a Cincinnati, Ohio, manufacturer of sliding gate regulators and control valves.

Pacific Semiconductors, Inc., Sub. of Thompson Ramo Wooldridge, Inc. in Los Angeles, will be expanded by integration with TRW Components Co., which consists of five electronic component manufacturing companies.

The Reliance Electric and Engineering Co., Cleveland, Ohio, has entered a joint venture company in Switzerland with Schindler & Co. Ltd. of Ebikon-Lucerne. Schindler-Reliance Electronics Ltd. will develop business in electric drives and electronic controls in the European markets.

Univis, Inc., Ft. Lauderdale, Fla., has set up a subsidiary, American Aerospace Controls in Farmingdale, N.Y. The new company will develop precision electromechanical devices, reflective optic components, and thin film transducers. Univis is the world's fourth largest producer of opthalmic lenses and also makes eyeglass frames and plastic lenses.

IMPORTANT MOVES BY KEY PEOPLE

Knowles in New R&D Post at Motorola Semiconductor

C. Harry Knowles has become assistant general manager for research and advanced development at Motorola, Inc.'s Semiconductor Products Div. in Phoenix, Ariz. He was formerly product manager for the company's mesa transistor products.

In his new post Knowles will head the division's development of integrated components and other devices and will direct its activities in mechanization and circuit research.

Knowles was with Bell Telephone Laboratories before joining Motorola.

Piccard to be Oceanography Consultant at Loral

Jacques Piccard, son of bathyscaph inventor, Auguste Piccard, and a pilot in the record depth bathyscaph descent, has become a consultant to Loral Electronics Corp. in its newly established oceanography program. Piccard will work with Dimitri Rebikoff, director of the New York firm's oceanography activity.

Rebikoff joined Loral in August with the acquisition of his products and patents and those of three French oceanography companies.

Other Important Moves

Leigh A. Brite has become vice-president in charge of the Technical Products Div. of Packard Bell Electronics, Los Angeles. He was formerly with the Aeronutronic Div. of Ford Motor Co. where he was manager of space electronics. He will head Packard Bell's activities in industrial electronics and communications.

Joseph H. Schlessel has been named president and general manager of the Western Design & Electronics Div. of U.S. Industries, Inc. Schlessel was executive vice-president of the Goleta, Calif., firm; he succeeds Hugh C. B[illegible]m who has resigned.

Dr. S. Roy Morrison has been promoted to assistant director of the Research Center of Minneapolis-Honeywell Regulator Co., Hopkins, Minn. Dr. Morrison had been senior staff scientist. He succeeds Dr. John R. Dempsey, who replaced Dr. Finn Larsen, now assistant army secretary.

Henry Epstein is now manager of the precision controls department of

Metals & Controls, Inc., a division of Texas Instruments, Inc. He has been with the Attleboro, Mass., firm since 1950.

Samuel M. Berkowitz is the newly announced manager of the Military Computer Engineering Dept. of Philco Corp.'s Computer Div. He'll direct the Willow Grove, Pa., company's Aerospace Computer Laboratory in the development of aerospace and other military computers.

Dr. Donald L. Farr, who directed the development of advanced missile and space system guidance theory while at General Dynamics/Astronautics, has joined the Librascope Div. of General Precision, Inc. He will be a staff engineer in the technical planning group of the Glendale, Calif., company's Aerospace Branch, working on guidance computers.

Richard L. Stone is now with the Electronics Group of General Mills, Inc. as an instrument and control system product manager in the Electronic and Mechanical Defense Products Dept. of the Minneapolis, Minn., company. Stone was formerly with GE where he was an advanced programs planning manager.

Dr. Frederick D. Ezekial has become general manager of a CompuDyne Corp. subsidiary, American Measurement and Control, Inc., Waltham, Mass. He was director of research and now succeeds Donald G. O'Brien, who will remain a consultant and director of CompuDyne. The Hatboro, Pa., company also has appointed Jack H. Bernstein general manager of CompuDyne Electronics, Inc., another subsidiary. He had been with the Stromberg-Carlson Div. of General Dynamics Corp.

Roger E. Gay will be the new managing director of American Standards Association starting in January. The former president of the Bristol Brass Corp. will succeed Vice Admiral George F. Hussey, Jr., who is retiring. Gay has been a management consultant and was ASA president in 1952-54.

Obituary

Sigurd Varian, 60; coinventor of the klystron and cofounder of Varian Associates; in light airplane crash off the coast of Mexico, October 18.

COMING NEXT MONTH

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  Describes in physical terms the action of a sampled-data controller that programs variable delays to compensate for process dead time.
- **Minimizing Structure Resonance Effects**
  Unique servo design, initially for shipboard tracking radar, maintains desired output (line-of-sight) independent of structure (ship) motion and dynamics and external torque load (wind).
- **Programmed Assembly Machine for Components**
  Automatic assembly of computer circuit cards cuts cost to $0.003 per insertion.
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  Logic circuits modify binary data, keeps error signal independent of angle and stops transition ambiguity.
- **Phase Angle Loci of Distribution Lag**
  Data File contains basis, nomograph, and example for solving a difficult problem.
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3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
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NEW PRODUCTS & BULLETINS

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480—Applying Control Timers, 50 cents
478—Servo Modulators, 65 cents
477—Basic Data on Process Control Systems, 50 cents
476—Three Ways to Simulate Dead Time, 15 cents

Equipment Index

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CONTROL BITS

Military Electronic Light Valve (MELVA) projection system will display data transmitted by the MIDAS infrared spy-in-the-sky satellites. Built by General Electric Co., the MELVA displays will show multicolor data in real time under normal light conditions on a TV-size console or a 6 x 9 ft screen.

•

Transistor driven magnetic amplifiers are used in a 13-kw power supply made by Airpax Electronics, Inc. for RCA's 601 computer. The $25,000 supplies regulate six critical voltages to within ¾% of rated output.

•

Eight Robotugs, electronically guided transfer trucks designed by EMI Electronics Ltd., are used to move 1,000 tons of material per day between rail cars and trucks at a Paris station. Wires buried below ground carry route signals to guidance equipment in the tugs. Routes are divided into 84 blocks, with one tug allowed in a block at a time.

•

Soviet steel industry has blossomed out with two computer control systems. One controls melting in arc furnaces, at the Zaporozhiye works. A kiev computer controls experimental melts at the Dnieproderzinsk works, 500 kilometers away.

CATALOGS AND BULLETINS

The first three items describe examples of especially useful applications literature. They can be obtained by circling the indicated numbers on the reader service cards, as can the other new literature items, except the fourth, which requires direct request to the manufacturer.

Two handbooks

Two new volumes have been published in this manufacturer's Technical Information for the Engineer handbook series. The seventh edition of the section on motors, motor-generators, and synchros (400) provides 60 pages of updated information on the theory, performance, application, construction, and testing of these rotary wound components. Tables give operating characteristics of more than 250 units used in servosystems, computers, and other applications. A new handbook added to the series covers testing and test equipment (401). This 46-page publication gives detailed descriptions of tests of synchros, resolvers, servomotors, motor-generators, gyros, and accelerometers. The handbooks make generous use of photos, schematics, block diagrams, and tables.—Kearfott Div., General Precision, Inc. **Circle No. 400 or 401.**

Precision bearings

This leatherette covered, wire bound Catalog 6 provides 64 pages of detailed information on precision bearings from the miniature up to the instrument sizes. Besides pages of tabular information on this manufacturer's bearings (these include full specifications, dimension drawings, and actual size drawings), the publication contains a useful handbook section which covers bearing nomenclature, selection, ratings, testing, and lubrication in considerable detail. A section of typical applications is also included.—Miniature Precision Bearings, Inc. **Circle No. 402.**

Digital circuits

Chapters on basic logic design principles (including a concise explanation of Boolean algebra), graphic symbols (with new USAF symbology), logic modules, and circuit configurations are included in this new 68-page handbook. The latter two sections, covering 48 pages of publication S-139, give complete descriptions and specifications of the manufacturer's line of digital modules and circuit aids for applying them.—Interstate Electronics Corp., Anaheim, Calif. **Circle No. 403.**

GROUND SUPPORT, TEST EQUIPMENT. Kidde Aero-Space Div., Walter Kidde & Co., Inc., Belleville, N. J. Booklet 32 pp. Describes the unique custom electronic devices manufactured by this company's Electronics Laboratories. Missile ground support equipment includes an automatic startup and checkout system and a van-mounted mobile telemetry setup. Test equipment items described by photographs, sketches, and specifications include a radar target simulator, a cable test set, and testing units

for motors, tranistsors, and power rectifiers. Automated order and billing system and a numerically controlled punch press are also noted.

CONTROLLED PUMPS. The Oilgear Co. Bulletin 47740, 22 pp. Two-color illustrated booklet covers a complete line of electrohydraulic, servo controlled pumps and system components. Cutaway flow drawings show how the pumps and components work and what function they perform. Units are illustrated, and tables of specifications and dimension drawings are included. Among the components covered are transistorized amplifiers, feedback transducers, relief valves, and special assemblies. Wiring diagrams are given for typical systems. **Circle No. 404.**

SPECIAL PRODUCTS. Fairchild Semiconductor, Div. of Fairchild Camera and Instrument Corp. Brochure, 44 pp. Pictorial tabular descriptions are given for more than 100 special semiconductor products. Tables give schematic diagrams, similar standard device type, header type, and drawings of lead configurations. **Circle No. 405.**

METER RELAYS. Assembly Products, Inc. Bulletin, No. 5, 24 pp. Complete information is given on locking-contact meter relays, including operating features and circuits to be used for achieving the most used forms of control action. Two-color drawings and complete text description show how the relays operate. Schematics of typical circuits with circuit descriptions are given. Bulletin covers continuous reading meter relays, relays with isolated coils and double locking coils, and control components used with meter relays. Notes are given on response time, damping, and overload protection. **Circle No. 406.**

POWER SUPPLY LISTING. Perkin Electronics Corp. Notebook size, foldout chart lists output, regulation, ripple, impedance, dimensions, and prices for all laboratory dc supplies and ac line regulators produced by this manufacturer. **Circle No. 407.**

SI RECTIFIERS. Rectifier Capacitor Div., Fansteel Metallurgical Corp. Catalog, 44 pp. Consists of 12 individual data bulletins describing eight basic silicon power rectifiers and their corresponding standard stack assemblies. This two-color publication includes complete tabulation of electrical data, characteristic curves, photographs, and dimension drawings. Rectifiers covered range from 6 to 240 amp with maximum PRV ranging from 50 to 600 volts. Rated outputs of rectifier stacks range from 12 to 370 amp, single phase and from 18 to 520 amp, three-phase. **Circle No. 408.**

CHROMATOGRAPHY. The Foxboro Co. Brochure PD11, 14 pp. Illustrated folder gives a basic introduction to chromatographic analysis and describes the manufacturer's B6025 unit. Technical descriptions of the analyzer's components are included. **Circle No. 409.**

CIRCUIT MODULES. Electronic Modules Corp. Catalog, 32 pp. Describes a line of 250-kcps circuit modules. Following introductory section, complete data sheets are given for each device on the line. These are complete with photographs, base drawings, specifications, and

Catalogs & Bulletins

schematics. A price list is also included. **Circle No. 410.**

ELECTROMECHANICAL COMPONENTS. Siamco, Div. of Tech-Ohm Electronics, Inc. Catalog 100, 140 pp. Pocket size publication describes the manufacturer's line of electronic and electromechanical components, including precision gears, magnetic clutches and brakes, differentials, couplings, gear heads, limit stops, bearings, and electronic equipment hardware. Dimension drawings, tables of specifications, and prices are included. **Circle No. 411.**

DATA ACQUISITION SET. Consolidated Systems Corp. Bulletin 3047, 16 pp. Describes MicroSADIC integrated high speed, general purpose digital data acquisition system. Well illustrated booklet goes into considerable detail and uses specialized photographs to tell the story of this equipment. A table of complete specifications is included. **Circle No. 412.**

HYDRAULIC MOTORS. Aero Hydraulics Div., Vickers, Inc., Div. of Sperry Rand Corp. Bulletin A-5283, 4 pp. Covers variable displacement hydraulic motors for use with ac generators, fuel boost pumps, turbine starters, and compressors. Bulletin describes high efficiency and control accuracy as features of these units. Dimension drawings and complete specifications are included. **Circle No. 413.**

THERMISTORS, VARISTORS. Victory Engineering Corp. Catalog V. 680, 10 pp. Provides information on a line of over 600 thermistors and varistors. A useful page of definitions is included, and available units are illustrated by dimension drawings and described in detailed tables. Devices are available as beads, rods, discs, washers, or in assemblies. **Circle No. 414.**

ELECTRIC GAGING. Industrial Products Div., Hamilton Watch Co. Booklet, 8 pp. Explains the function of the manufacturer's indicator and control units used in electric gaging on fabrication and inspection lines. Photographs and simple schematics of the unit are included, and drawings of indicator and control installations are supplied. **Circle No. 415.**

DATA LOGGER. The Bristol Co. Bulletin D401, 6 pp. Describes the DataMaster automatic data logger. Photographs show equipment in use in several applications. Details on the operation of the logger are given, and examples of log sheets are reproduced. **Circle No. 416.**

DIFFERENTIAL TRANSFORMERS. Automatic Timing & Controls, Inc. Bulletin 6208, 12 pp. Along with covering theory and application of the manufacturer's line of LVDT's, this publication tabulates complete specifications and prices of these components. Wiring drawings and photos are included. **Circle No. 417.**

IMPULSE TRANSMITTERS. Landis & Gyr, Inc. Folder, 4 pp. Five Sodeco impulse transmitters, which transform motion into electrical counting pulses, are illustrated and concisely described in this publication. Specifications and dimension drawings are included for rotary motion unidirectional, bidirectional, lever actuated, fixed time ratio, and adjustable time ratio

types. **Circle No. 418.**

INDUSTRIAL RELAYS. Hillburn Electronics Corp., Sub. of Loral Electronics Corp. Short form catalog, 6 pp. Specifications, operating information, and general applications data on a line of relays for industrial and commercial use are given in this condensed catalog. Photograph of each unit is accompanied by a thumbnail description. Ordering information and mounting dimensions are also included. **Circle No. 419.**

VERSATILE COMPONENT. Raytheon Co., Industrial Components Div. Bulletin, 12 pp. Technical paper describes applications of the manufacturer's versatile Raysistor component. The electro-optical device is applied to chopper, modulator, switching, and control circuits. Schematics, graphs, and waveforms are used to illustrate operation. **Circle No. 420.**

INSTRUMENT CHOPPERS. James Electronics, Inc. Catalog, 12 pp. Describes manufacturer's line of general instrument choppers giving complete information on miniature spdt and dpdt models. A useful section on definitions and specifications is featured. Units are covered by tables of specifications and dimension drawings. **Circle No. 421.**

BEARING DATA SHEET. The Barden Corp. Data Sheet M-3. This handy card contains selection data in tabular form on 143 standard and special design miniature and instrument bearings. Sizes covered range from 0.1562 to 1 in. OD. Information given includes dimensions, dynamic ratings, and static capacity. A page of engineering information includes a guide to nomenclature, information on static and dynamic capacity, and charts of torque values. **Circle No. 422.**

RECORDERS. General Electric Co. Bulletin GEA-6887A, 12 pp. Covers this manufacturer's line of single and multipen null-balance recorders and recorder-controllers. Operating features are described using annotated cutaway photographs. Various units in the line are illustrated, and complete specifications are included for them. A list of typical measurements that these recorders can perform is given, along with details on where more information on these applications is available. **Circle No. 423.**

NUCLEAR SYSTEM INSTRUMENTS. Physical Sciences Corp., an affilate of Packard-Bell Electronics. Catalog S/I-1-61, 16 pp. Covers a line of instruments and systems designed for use in nuclear systems work. Featured is a creep capsule system designed to monitor and measure nuclear temperature, pressure, and creep under conditions of reactor-on and reactor-off. Photographs are used to describe this and other instruments including electromicrometer, digital transducer monitor, digital millivoltmeter, and microvoltmeter. **Circle No. 424.**

INSTRUMENT COUNTERS. Durant Manufacturing Co. Catalog 400, 16 pp. Specifications and detailed descriptions are given for a line of mechanical and electrical instrument counters. Detailed dimension drawings are given for entire counters and for number wheels. Special counters which have developed are described to demonstrate the devices' versatility. **Circle No. 425.**

ABSTRACTS

Altimeters evaluated

From "Survey of Altitude-Measuring Methods for the Vertical Separation of Aircraft," by William Gracey. National Aeronautics and Space Administration Technical Note D-738. March, 1961.

Several altitude measuring methods have been examined to find the most accurate system for maintaining vertical separation of aircraft.

The gravimeter and integrating accelerometer are unsuitable because the desired accelerations are hard to measure accurately in the presence of aircraft motion accelerations. Gravity measurement is also complicated by the small change with height (0.01 g per 100,000 ft). In the integration of vertical acceleration, small acceleration errors quickly propagate to height errors.

The cosmic ray altimeter and magnetometer are unsatisfactory because cosmic ray and magnetic field intensities change markedly during natural disturbances. Also, magnetic field variation with height is influenced by local anomalies. Capacitance and sonic altimeters are eliminated by their limited range (about 200-300 ft).

Radio altimeters are also unsuitable because of limited range (about 10,000 ft). Radar altimeters possess sufficient range (probably up to 100,000 ft) and, according to manufacturer's claims, high accuracy (±22 ft +0.025 percent height). But since terrain character can cause false indications, this type of altimeter could be used for vertical separation purposes only over the ocean.

Of the pressure measuring instruments, the limited-range altimeter, the hypsometer, and the statoscope all look attractive from an accuracy standpoint only through a limited height range at high altitudes. Similarly, the effect of humidity at low altitudes limits the utility of density altimeters to altitudes above 30,000 ft. To realize the possible advantage in accuracy of these instruments would require an auxiliary instrument to establish an initial reference height.

A full-range altimeter with servo-type mechanisms for measuring static pressure and applying corrections for static pressure error can provide a system accuracy of ±90 ft at an altitude of 40,000 ft and ±200 ft at 70,000 ft. A full-range mechanical altimeter with the precision-type mechanism can provide a system accuracy of ±70 ft at 40,000 ft and ±265 ft at 70,000 ft

ABSTRACTS

if corrections for scale error and static pressure error are applied manually. In a recently developed altimeter system a precision-type altimeter has been combined with a static pressure computer-compensator system to provide an integral mechanical standby. It is believed that this system will be operationally satisfactory and will provide the ±250 ft accuracy required for 1,000-ft separations over the complete altitude range up to 70,000 ft.

For minimum static pressure error at supersonic speeds, minimum effect of angle of attack, and good error repeatability over a long period of time, the static pressure tube should be located ahead of the most forward part of the airplane.

Reliabilty by redundancy

From "Redundancy and the Detection of First Failures", by D. C. James, A. H. Kent, and J. A. Holloway, Paper No. 16/1, presented at the Western Electronic Show and Convention, San Francisco, Calif., August 22-25, 1961.

Emphasis on reliability can be expected to increase due to system user demands, demands of technological warfare, and the long service life demands of space equipment. Reliability improvement methods available are of five general types: 1, component part improvement; 2, derating; 3, circuit simplification; 4, maintenance, production techniques; 5, redundancy.

These are examined in order. The authors urge full exploitation of the first four methods before consideration of redundancy. To explain reliability using redundancy, four kinds of redundancy are calculated—non-redundant, parallel redundant, series redundant, series-parallel redundant.

Majority vote and dissenting vote indication redundant logic types are then examined in detail for their effect on reliability. In appendixes, reliability equations are developed for the fundamental redundancies.

Contactless potentiometer

From "A Contactless Infinite Resolution Potentiometer", by P. H. Wendland, Paper No. 5/1, presented at the Western Electronic Show and Convention, San Francisco, Calif., August 22-25, 1961.

Conventional potentiometers are limited in speed and useful life be-

cause of the mechanical action of the sliding contact. To overcome these and certain other shortcomings, a potentiometer with an optical-electronic wiper was developed. The device is so arranged that a movable light beam defines a highly conductive path between the resistive track and collector. The potential "seen" by the load is thus the potential that exists on the resistive track at the light beam's position, giving the same effect as sliding a mechanical contact along a resistive wire. Efforts are being made to improve the device by better manufacturing techniques and investigations of a radioluminescent light source instead of a miniature bulb. Using a Beta emitting radioisotope and radioluminescent source, a typical usable life of 9.4 years is expected.

On-line information system

From "A Tallimarker Model: Recording and Identifying the Flow of Production", by W. L. Marks and D. J. Mayes. Paper presented at a meeting of the Society of Instrument Technology, London, January 11, 1961.

The Tallimarker is a system for collecting and recording information and tallying it with the flow of material through a process. The scheme calls for 1) information input stations at key points along the production line, 2) information output (display) stations at the same or other key points to tell operators what they need to know about the product, 3) a centrally situated information store with at least as many channels as the maximum number of items that will be processed simultaneously, and 4) readout and printout facilities at a central production control office.

A simplified working model Tallimarker has been constructed based on imaginary ingot processing in a steel works. Four stations represent the soaking pits, primary mill, bloom shears, and delivery office. The first three are equipped with push buttons for feeding information into the system and all have digitron numerical displays that register the identity and history of blooms being processed.

As each ingot is drawn from the soaking pit it is given an identity number by the soaking pit operator. This number is written into one memory level of the uniselector store when the operator presses an ingot out but-

ton. Each time this button is pressed it steps a level selector so that the identities of succeeding ingots are written into one memory level after another in succession.

The level selector associated with the primary mill is one level behind the one at the soaking pit. As soon as the first ingot arrives at the mill the memory is interrogated and the information is read out nondestructively and displayed. The ingot is duly reduced in the mill, and the dimensions are punched into the memory.

Similarly, the shear operator sees the identity and dimensions of each ingot as soon as it arrives at his station. He cuts the ingot into blooms and adds the number to the history in the memory level. At the delivery office the original identity and accumulated history of each bloom is read out and displayed as soon as each leaves the production line. When the information on any memory level in the store becomes complete it is read out onto punched tape and the memory level is once more available.

Written and oral modes of material identification are replaced by precise printed records. A complete history is stored centrally, but each operator is provided only with information he needs.

Optical readout

From "Optical Read-out of Digital Magnetic Recording", by J. J. Miyata, Communication and Electronics, March 1961, No. 53, pp. 53-58. Published by American Institute of Electrical Engineers.

Magneto-optic effects created by interaction between light and magnetized matter are of several types: polarization, double refraction, and modification of the plane of polarization (Farady and Kerr effects). The system described (Magop) uses the Kerr effect. The light source and phototube are set up at appropriate angles to optically read the magnetized material. Angles, polarizers, light sources, photo detectors, photo detector and film noise, and magnetic coatings are discussed.

Magop is most useful where loss of signal resolution is caused primarily by the separation of a readback head from the coating. Using a light beam for reading eliminates this loss. Since the signal depends on surface magnetization, a thin film can be used to obtain high storage density.

ABSTRACTS

Error definition

From "Accuracy in Process Computer Instrumentation Systems", by W. M. Gaines and W. N. Patterson, AIEE Paper No. CP 61-186, presented at Winter General Meeting, New York, N. Y., Jan. 29-Feb. 3, 1961.

Users should demand and receive a composite figure for both system accuracy and repeatability. This will not make a user's task easier. Rather, it places on him the burden of thoroughly defining conditions under which the system must work.

By describing the design of digital control computer systems, and the pertinent definitions, the authors hope to help avoid many of the problems that have arisen in past systems. Definitions are supplied for accuracy, repeatability, common mode errors, zero offset errors, drift errors, linearity errors, gain errors, errors due to noise, quantization errors, and accuracy versus repeatability. The definitions are clear and usable and should help in specifying system accuracy.

Laser ranging

From "Design and Operation of an Experimental Colidar", by E. J. Woodbury, R. S. Congleton, J. H. Morse, and M. L. Stitch, Paper No. 30/1, presented at the Western Electronic Show and Convention, San Francisco, Calif., August 22-25, 1961.

Coherent collimated light from a ruby laser offers two main advantages for optical ranging. First, the output is from a small aperture, collimated into a narrow cone. The transmitted cone of light, 7 or 8 ft in diam at a 5-mile range, is completely intercepted by most targets. Second, the laser output is monochromatic; narrow optical filters can be used in the receiver to increase the discrimination against sunlight noise.

In designing a laboratory model to demonstrate these basic advantages, difficulties not normally faced by electrical engineers were encountered. These difficulties, involving the laser exciter, the receiver, and various noises, are discussed, and the design methods described. Certain amplitude anomalies between the transmitted and received pulses are assumed to be due to some sort of filiamentary substructure in the laser beam.

NEW BOOKS

Two on transistors

BASIC TRANSISTORS. Alexander Schure, 152 *pp. Published by John F. Rider Publisher, Inc., New York.* $3.95.

SEMICONDUCTORS AND TRANSISTORS. *Edited by Alexander Schure,* 144 *pp. Published by John F. Rider Publisher, Inc., New York.* $2.90.

Anyone looking for a first book on transistors would do well to pick one of these paperbacks (the first is also available in hard cover). The "pictured text" *Basic Transistors* is an easily read guide to understanding transistors and how they work in a wide range of commonly used circuits. *Semiconductors and Transistors* includes fewer applications (it concentrates on the design and analysis of amplifiers), but its coverage in depth makes it a better foundation for more advanced study.

Both books begin with atomic structure and explain what makes semiconductors different from insulators and conductors. The analysis in *Semiconductors and Transistors* is more thorough, but the material in *Basic Transistors* is sound and satisfying. Both discuss PN junction diodes, transistors, their characteristics and ratings, and the three basic transistor connections. *Basic Transistors* goes on to amplifier, interstage coupling, and oscillator circuits, and power and tetrode transistors. *Semiconductors and Transistors* discusses load lines, biasing, establishing the quiescent operating point, and regions of operation, and ends with a chapter on small signal analysis which describes the use of an equivalent circuit to simulate a transistor's performance with relatively small or feeble input signals.

Dictionary revised

THE INTERNATIONAL DICTIONARY OF PHYSICS AND ELECTRONICS, 2ND EDITION. 1355 *pp. Published by D. Van Nostrand Co., Inc., Princeton, N. J.* $27.85.

Progress has demanded a second edition of this widely used standard in less than five years. Besides up-todate definitions in electronics, astrophysics, nuclear physics, and magnetohydrodynamics, there is a new 36-page review of the major developments in physics. The latest IRE definitions are here, as are new French, German, Russian, and Spanish indexes.

NEW BOOKS

Photometric Papers

INSTRUMENTATION AND HIGH-SPEED PHOTOGRAPHY, VOL. 1, SERIES II. 187 pp. *Published by the Society of Motion Picture and Television Engineers, New York.* $4.

A survey of photographic and television instrumentation techniques is given in this collection of 43 papers reprinted from the SMPTE Journal. Some 15 papers deal directly or indirectly with missile photography and optical tracking. Other topics range from submicrosecond photography of explosions to rattlesnake strike studies to special light sources, cameras, and cathode ray tubes.

Photocell Reference Book

INTERNATIONAL RECTIFIER SOLAR CELL AND PHOTOCELL HANDBOOK. *John Sasuga.* 112 pp. *Published by the International Recifier Corp., El Segundo, Calif.* $2.00.

This little manual, a revised version of one first published in 1955, should be of interest to hobbyists and engineers alike. There is a chapter on basic radiation theory and photometric nomenclature, but most of the book is devoted to circuits and applications. Photometers and densitometers, photoelectric relays, beam illuminators, and "electric-eye" cameras as well as numerous devices of a more "gadgety" nature are discussed, and there is some interesting material on the use of silicon cells in space vehicles. Specifications and performance curves of International Rectifier selenium and silicon cells are included, plus data on the batteries and meters used in the circuits. There are 25 references in the book.

Abbe to Zener

A DICTIONARY OF NAMED EFFECTS AND LAWS IN CHEMISTRY, PHYSICS AND MATHEMATICS, 2ND EDITION. D. W. G. Ballentyne and L. E. Q. Walker, 234 pp. Published by the Macmillan Co., New York. $6.

This glossary of theorems, principles, laws, processes, tests, coefficients, reactions, factors and phenomena can save the engineer a great deal of searching through specialized texts. Entries are listed alphabetically, and the new edition includes some 150 new definitions.

NEW BOOKS

Process Instrumentation Data

MANUAL ON INSTALLATION OF REFINERY INSTRUMENTS AND CONTROL SYSTEMS. 107 *pp. Published by the American Petroleum Institute, New York.* $4.

This is a handbook devoted to the installation and application of the more generally used measuring devices, controllers, valves, instrument panels, air and electrical supply systems, and hydraulic systems. Although prepared for petroleum refineries, much of the information is applicable to chemical and gasoline plants and similar installations. Short excerpts were published in CtE for January '60 (p. 137) and March '60 (p. 115).

Practical logic techniques

TRANSISTOR LOGIC CIRCUITS. *Richard B. Hurley,* 363 *pp. Published by John Wiley & Sons, Inc., New York.* $10.

This book treats logic mathematics and applied logic circuitry in a realistic and practical manner. It provides a much needed supplement to existing transistor theory and circuit books for students and practicing engineers.

An introductory chapter on binary arithmetic is followed by one on Boolean algebra presented in a form suitable to switching theory. Diode logic circuits are examined in chapter 3, and chapters 4 and 5 investigate theoretical techniques for minimizing the number of components in a system.

Chapter 6 treats equivalent circuits and dynamics of the triode switch. In the next two chapters, several system logic plans employing triode transistors are examined with practical examples. Chapters 7 and 8 are concerned with logic of voltage and current switching.

Thus far, the text has emphasized switching logic associated with combinational circuits. Chapter 9 introduces sequential logic as employed for characterizing flip-flop memory and input properties, with emphasis on counters and registers. Chapter 10 treats sequential logic as applied to minimizing the number of memory elements. The last two chapters cover bistable, monostable, and astable regenerative transistor circuits peculiar to sequential systems.

A. N. DeSautels
Golden Valley, Minn.

NEW BOOKS

Space tableau

ARTIFICIAL EARTH SATELLITES AND SUCCESSFUL SOLAR PROBES. 1957-1960. *Walter H. Stafford and Robert M. Croft, 602 pp. Published by the National Aeronautics and Space Administration (NASA Technical Note D-601), Washington, D. C.* $8.

This volume contains information on all successful satellites and space probes, American and Russian, launched through 1960. Descriptions are given of launching conditions, scientific experiments and accomplishments, and results of orbital measurements for each satellite or probe, arranged in chronological order of launching. The most complete data available on each mission is provided in the form of tables giving orbital data at various times during the life of each satellite; graphs of perigee and apogee altitudes versus date and period versus date; photographs of satellites, probes and launching vehicles.

Sampled data introduction

EINFÜHRUNG IN DIE THEORIE DER ABTASTSYSTEME (INTRODUCTION TO THE THEORY OF SAMPLED DATA SYSTEMS). *Johann Tschauner, 185 pp. Published by R. Oldenbourg Verlag, Munich, Germany. In German. 32 Deutsche marks.*

Sampled data systems receive input information in the form of periodic impulses that can be amplitude, length, or phase modulated. This book concentrates on amplitude modulated systems, which are used regularly with digital computers and yield more easily to mathematical treatment. The first part is about open-loop systems, the second about closed-loop systems, and the third about mathematical theory.

This is not a beginner's text, and the reader needs a working knowledge of systems analysis and basic mathematical tools like transfer functions and Laplace transforms. The author's intent is to introduce German readers to the sampled data theories contained in American and Russian publications. The book gives no numerical examples and contains no references to hardware, but it does provide a thorough introduction to an important area of control theory.

Werner G. Holzbock

MEETINGS

DECEMBER

National Aerospace Support and Operations Meeting, sponsored by Institute of the Aerospace Sciences; San Juan Hotel, Orlando, Fla. Dec. 4-5

Eastern Joint Computer Conference (EJCC), sponsored by IRE/PGEC, AIEE, ACM; Sheraton-Park Hotel, Washington, D.C. Dec. 12-14

Forum on Electronic Computers, sponsored by Joint Committee on Continuing Legal Education of the American Law Institute and the American Bar Association; Statler-Hilton Hotel, Los Angeles, Calif. Dec. 14-16

JANUARY

Eighth National Symposium on Reliability and Quality Control; Statler-Hilton Hotel, Washington, D.C. Jan. 9-11

17th Annual Instrumentation Symposium, sponsored by A & M College of Texas; College Station, Tex. Jan. 24-26

FEBRUARY

1962 National Winter Convention on Military Electronics, sponsored by IRE/PGMIL; Ambassador Hotel, Los Angeles, Calif. Feb. 7-9

Short Course in Automation, Computers, and Instrumentation, sponsored by ISA and School of Industrial Engineering, Georgia Institute of Technology; Georgia Tech Campus, Atlanta, Ga. Feb. 12-16

Ninth Annual International Solid-State Circuits Conference, sponsored by IRE, AIEE, University of Pennsylvania; Sheraton Hotel and University of Pennsylvania campus, Philadelphia, Pa. Feb. 14-16

International Seminar on Automatic Control in Iron and Steel Industry, organized by Institut Belge de Regulation et d'Automatisme and sponsored by International Federation of Aütomatic Control, Association Internationale pour le Calcul Analogique, Communaute Europeenne du Charbon et de l'Acier, Belgian Ministries of Economic Affairs and National Education; Brussels Palais des Congres, Brussels, Belgium. Feb. 19-23

What's Available in Reprints

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Single copies of any reprint can be obtained at the nominal cost listed below by circling the corresponding numbers on a reader service card, p. 156. Don't send money with card, we will bill you later. For multiple copies write Reprint Dept. Quantity rates will be quoted on request.

513—Measuring With Solid State Transducers, 16 pp. Contains all articles from the Measurement section of Control Engineering's September 1961 theme issue on Solid State in Control. Covers piezoelectric and piezoresistive strain gages, Hall effect transducers, semiconductor thermometers, and a number of devices for sensing radiant energy based on various solid state phenomena. Variables that can be measured with such transducers include temperature, strain, power, current, magnetic field strength, and displacement. 50 cents.

512—Ready Reference Data Files—IV, 20 pp. Contains Data Files 37 to 48. Subjects range from information display to semiconductor voltage regulators to loaded parallel-T filters. 50 cents.

511—Industrial Process Chromatographs: What they do, How they work, Who makes them, 14 pp. Reviews basics of chromatographic techniques including latest refinements to increase sensitivity and reduce analysis time of this versatile stream analyzer, describes major components and their functions, and highlights operation and specific features of six commercially available chromatographs. 50 cents.

510—The Use of Digital Computers in Scieuce, in Business, and in Control, 112 pp. A collection of 14 articles published over a two-year period as the Digital Applications Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and military. (An old reprint but with basic and practical content of value today). $3.00.

509—Applying Incremental Servos, 24 pp. Incremental servos offer many advantages in closed-loop systems. A grouping of five basic articles compares stepping and stepless control, describes the operation and analysis of solenoid-ratchet and phase-

Computer Comparison Reprints

CONTROL ENGINEERING's Computer Equipment Comparison Series by Cresap, McCormick and Paget is now available in special looseleaf handbook format on a subscription basis. Subscribers to this service will receive a gold embossed binder plus a set of specially designed reprints of all articles published since the beginning of the series in the October 1961 issue of CtE. The service will then continue by automatic mailing of all future reprints soon after each article appears. The prepunched reprints will be printed on one side only with all comparison tables horizontal, on fold-out pages if necessary. The entire series will run for about 24 articles, and updating articles will be published as the series progresses.

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pulsed synchronous steppers, shows 16 applications of stepping motors, tabulates pertinent characteristics of available stepping motors, and discusses the problems of interlocking the devices. 65 cents.

508—Transistor Switches for Industrial Service, March 1961, 24 pp. Industry requires reliable, inexpensive, and fast switching devices. This special report thoroughly covers one possible solution to this requirement—transistor logic modules packaged for industrial use. Topics include how transistors perform logic functions, available systems and components, tips on selection and use, and case studies of industrial applications. 65 cents.

507—Tips on the Use of Electromechanical Relays, 24 pp. Compilation of five articles presents practical information on the design, test, and use of relay control systems. Topics covered include: testing relay electrical reliability, improving system reliability, narrowing relay differential, logical synthesis of systems, and verifying relay control circuits. 65 cents.

506—What You Should Know About Adaptive Systems, 17 pp. Is there such a thing as an adaptive control system? What approaches have been taken? What does the future hold? These are the questions the author answers in this three-article reprint, in sufficient detail and with sufficient references to provide a basic grounding in this latest area of control engineer interest. 50 cents.

505—The Basics of Optimum Response Relay Servos, 17 pp. Three part series summarizes all of the important design techniques that have been used to optimize the response of relay servos. The reprint describes the development of the optimum switching criteria, and outlines the progress that has been made in implementing this theory with hardware for second order and higher order systems. Extensive references provide a guide for further study. 50 cents.

504—System Characteristics of Modern Guidance Techniques, August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern techniques in celestial navigation, and perceptive guidance systems. 65 cents.

503—How to Determine Stream Analyzer Dynamics, 8 pp. Package of two articles shows how analyzers can introduce dynamic errors, how to determine analyzer dynamics, and how to improve performance. The instrument used is a differential refractometer but techniques can be extrapolated to other types of analyzers. 40 cents.

502—Survey of Dynamic Display Techniques, 20 pp. The function of these newly developed techniques is to put up-to-date information in the hands of human operators of control systems when the information changes at a high rate. Both basic approaches and commercial hardware are discussed for cathode ray tube displays, optical systems, and miscellaneous devices ranging from TV pickup to matrix cells. 50 cents.

501—Six Transducers for Precision Position Measurement, May 1960, 6 pp. Explains operation and gives practical ap-

(*Continued on page 176*)

REPRINTS cont'd

plication hints for six precision position transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

500—Ready Reference Data Files—I, II, III, 76 pp. The feature here is a special rate for those who purchase all of the Data Files published in CONTROL ENGINEERING through April 1960. The 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. $1.35.

496—How to Specify Instrument Accuracy, 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

494—How to Use the Root Locus in Control System Design, 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, determine transient response, and use locus techniques with multiloop systems. 45 cents.

489—Fundamentals of Multivibrators, 12 pp. Multivibrators are the electronic equivalent of the double-throw electromechanical relay and can perform substantially the same functions (memory, logic, gating, counting), but at enormously higher speeds. They can be built around vacuum tubes, transistors, square-loop magnetic materials, neon tubes, thyratrons, and cryotrons. This covers a broad selection of multivibrator circuits. 45 cents.

488—A Roundup of Control System Test Equipment, 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. 60 cents.

487—Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Regarded as constant speed devices, multispeed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, slip-frequency injection, use of eddy-current couplings, etc. 50 cents.

486—A New Way to Select the Best Control-system Control Valve, 16 pp. This three-article reprint gives rules for selecting the right valve characteristics based on static and dynamic considerations, takes into account the influence of piping on valve performance, and tackles the problem of sizing valves for maximum flow and for control rangeability. 50 cents.

485—Fundamentals of Tie-Motor Control, 12 pp. Although high powered

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Sworn to and subscribed before me this 18th day of September, 1961.

[SEAL] JANET A. HARTWICK.
(My commission expires March 30, 1963)

REPRINTS cont'd

synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try basis. The reprint examines the types of motors that can be used in the light of the application characteristics, and considers the special circuit designs that are required. 30 cents.

484—Applying Phase-Time Techniques to Nonlinear System Design, 16 pp. This series of three articles is designed to teach the use of phase-plane techniques to working system designers, on a practical rather than theoretical basis. It tells how to construct a phase-plane plot, interpret a plot in terms of system performance, and synthesize nonlinear systems using phase plane techniques. 50 cents.

483—Economics in Control, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

480—Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their characteristics and techniques for custom-designing controls for time-based routines. 50 cents.

478—Servo Modulators—Their Application, Characteristics, and Availability, 36 pp. A group of four integrated articles covering all phases of electromechanical, electronic solid state, and magnetic modulators. Typical circuit diagrams, characteristics, and applications are given for each type, plus an 84-item bibliography and tables listing commercial units. 65 cents.

477—Basic Data on Process Control, 24 pp. A grouping of five articles on flow-process control, including Basic Concepts of Feedback Control, Selecting Loops for Critical Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. 50 cents.

476—How to Simulate Dead Time, 6 pp. Three tricky techniques for simulating dead time or transport lag. One's electronic, another is pneumatic mechanical, and the third uses magnetic tape. A useful reference for control engineers concerned with process simulation. 15 cents.

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CONTINUED ON PAGE 180

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- ☐ Switching
- ☐ Systems Analysis
- ☐ Other ....

CATEGORY OF SPECIALIZATION

Please indicate number of months experience on proper lines

	Technical Experience (Months)	Supervisory Experience (Months)
RESEARCH (pure, fundamental, basic)	....	....
RESEARCH (Applied)	....	....
SYSTEMS (New Concepts)	....	....
DEVELOPMENT (Model)	....	....
DESIGN (Product)	....	....
MANUFACTURING (Product)	....	....
FIELD (Service)	....	....
SALES (Proposals & Products)	....	....

CIRCLE KEY NUMBERS OF ABOVE COMPANIES' POSITIONS THAT INTEREST YOU

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Control Engineering

WEEKLY QUALIFICATIONS FORM FOR POSITIONS AVAILABLE

(Continued from page 178)

COMPANY	SEE PAGE	KEY #
PILLSBURY COMPANY Minneapolis, Minnesota	198*	15
RAMO WOOLDRIDGE Div. of Thompson-Ramo-Wooldridge Inc. Canoga Park, California	179	16
SANDIA CORPORATION Albuquerque, New Mexico	75*	17
SIKORSKY AIRCRAFT Div. of United Aircraft Corp. Stratford, Connecticut	197*	18
P-7827	180	19

* These advertisements appeared in the November issue.

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(WN) What's New
(IP) Industry's Pulse

Unless otherwise designated, items are feature articles or Ideas at Work

Display of data (see also Information systems)

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Editorials

Electronics

Error analysis

F

Fiber optics

Flow-fluid

Foreign control (see also Russian control)

Frequency response

Function generators

G

Gaging

Graphic analysis

Gyros

Guidance

H

Hydraulics

I

Industrial control

Measuring

Medical applications

Meetings, news reports

Memories

Metals processing and finishing

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Nonlinear systems

Nuclear instrumentation

O

On-off control systems

P

Personality sketches

Pneumatics

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Process control

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AUTHOR INDEX

ADVERTISING IN THIS ISSUE

■

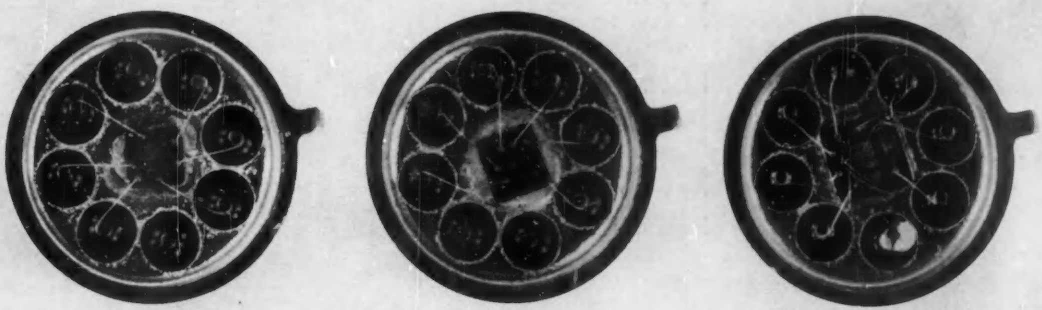
CLASSIFIED ADVERTISING
F. J. Eberle, Business Mgr.

ADVERTISERS INDEX

District Managers

ATLANTA 9: Robert C. Johnson, 1375 Peachtree Street N.E., 875-0523
BOSTON 16: Peter B. Stien, McGraw-Hill Bldg., Copley Square, COngress 2-1160
CHICAGO 11: Milton J. Steinbraker, 645 N. Michigan Ave., MOhawk 4-5800
CLEVELAND 13: Edward H. Walker Jr., 55 Public Square, SUperior 1-7000
DALLAS 1: John Grant, 2100 Vaughn Bldg., 1712 Commerce St., RIverside 7-9721
DENVER 2: John W. Patten, Tower Bldg., 1700 Broadway, ALpine 5-2981
HOUSTON 25: Gene Holland, W-724 Prudential Bldg., JAckson 6-1281
LOS ANGELES 17: Gene A. Fruhling, 1125 W. Sixth St., HUntley 2-5450
NEW YORK 36: J. M. Morris, R. Bauser, 500 Fifth Ave., OXford 5-5959
PHILADELPHIA 3: William F. Buehl, Six Penn Center Plaza, LOcust 8-4330
PORTLAND 4: S. Hubbard, Pacific Bldg., Yamhill St., CA 3-5118
SAN FRANCISCO 11: W. C. Woolston, 255 California St., DOuglas 2-4600
LONDON W. 1, ENGLAND: D. McDonald, 34 Dover St.
FRANKFURT-MAIN, GERMANY: S. Kimes, 85, Westendstrasse
GENEVA, SWITZERLAND: M. R. Zeynel, 2 Place du Port

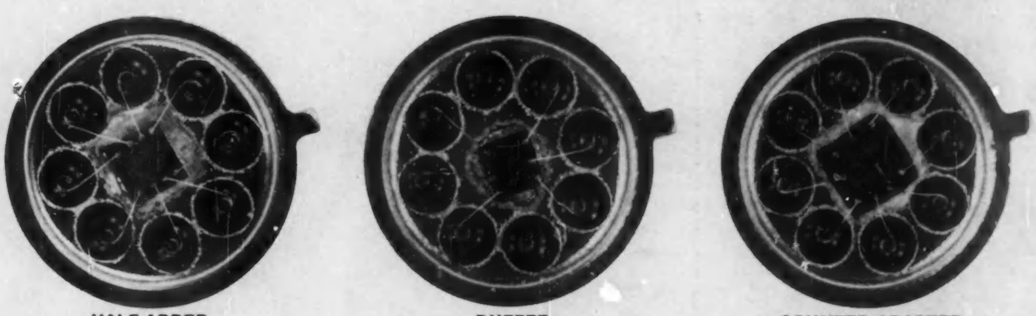
UNRETOUCHED PHOTOGRAPHS MAGNIFIED 4⅔ TIMES



FLIP-FLOP "F" Element

GATE "G" Element

HALF-SHIFT REGISTER "S" Element



HALF-ADDER "H" Element

BUFFER "B" Element

COUNTER ADAPTER "C" Element

MICROLOGIC ELEMENTS

are a compatible set of integrated digital functional blocks in which transistors and resistors are diffused via the Planar process into a single, monolithic chip of silicon. This family of functional elements is sufficient to efficiently fabricate a computer logic section. No other components are required.

They are designed to operate in a full military environment, over a temperature range of −55 degrees C to +125 degrees C. When integrated into a computer, they will operate at 1 mc clock rates over the above temperature range.

Micrologic elements are designed primarily to permit highly reliable data processing logic at very low cost. They make possible a simplified approach to the job and hence greatly reduce the lead time to the prototype computer.

The cost savings are to computer manufacturers and the computer user. The choice of the elements and the nature of the package, are great factors in the total cost reduction associated with the reliability, maintainability, repairability, logistics, and training.

The size reduction (one order of magnitude) gained with Micrologic is an important by-product of the main objectives of the program.

IMMEDIATE AVAILABILITY

All 6 Micrologic elements are available **now** for immediate volume delivery. Contact your Fairchild Field Sales Office.

90% COST REDUCTIONS IN LOGIC DESIGN & ASSEMBLY

Micrologic elements can cut logic system design and assembly costs up to 90%; space requirements up to 95%; power needs up to 75%. These savings are made possible through simplified layouts, standard handlings of TO-5 type packages, fewer inter-board connections, single clocks, one power supply.

PLANAR RELIABILITY

Fairchild Micrologic elements have been life tested for 1,000,000 element operating hours at 125° C without a single electrical failure. The Fairchild Planar process provides total protection with its integral oxide surface.

FAIRCHILD SEMICONDUCTOR

545 WHISMAN ROAD, MOUNTAIN VIEW, CALIF. • YORKSHIRE 8-8161 • TWX: MN VW CAL 853

A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

GENERAL SPECIFICATIONS FOR MICROLOGIC ELEMENTS

Speed	• 50 nsec. delay per stage for all loads (1 mc clock rates over temp. range of —55°C. to +125°C.)
Power	• 15 mW per node
Fan Out	• 5* over temp. range of —55° C. to +125° C.
Voltage	• 3 V ±30%
Package	• 8 lead TO-5 type (.170 height)

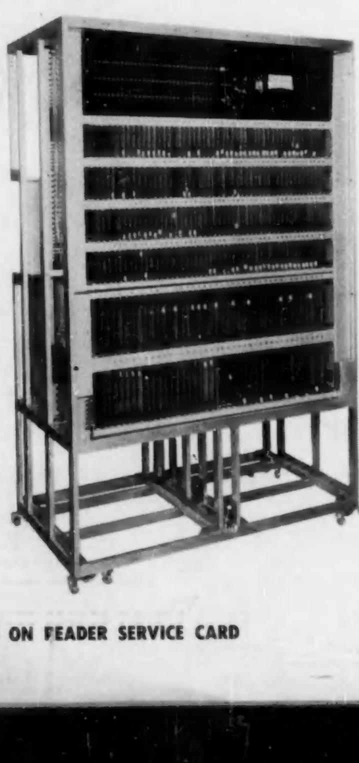
*The buffer element has a fan out of 25

CIRCLE 179 ON READER SERVICE CARD

1.5

EVERY-
BODY
TALKS
ABOUT
1.5
MICRO-
SECOND
CORE
MEMORIES

AMPEX SHIPS THEM



Truth is stranger than fiction. And here's the honest truth about the world's fastest, commercially available, random access core memory.

Ampex is delivering production line models of the new LQ ferrite core memory. The LQ executes a complete memory cycle in 1.5 microseconds. (Access time 1.0μ sec.) Capacity of standard models is 8192 or 4096 words up to 56 bits in length.

Bear in mind that the LQ is no hand-built mock-up, locked away in an R&D lab. Production line units, specifically designed, tested, rated and priced for commercial computer applications, are running, on line, in existing computer systems.

Right now Ampex is quoting deliveries of the LQ. Better write today for complete specifications and descriptive literature: Ampex Computer Products Co., P. O. Box 329, Culver City, Calif.

AMPEX 0/1 T.M.

AMPEX COMPUTER PRODUCTS COMPANY

CIRCLE 180 ON FEADER SERVICE CARD